ANGLO-CHINESE JUNIOR COLLEGE
DEPARTMENT OF CHEMISTRY
Preliminary Examination

CHEMISTRY **9729/01**
Higher 2

Paper 1 Multiple Choice

14 September 2021
1 hour

Additional Materials: Multiple Choice Answer Sheet
Data Booklet

READ THESE INSTRUCTIONS FIRST

Write in soft pencil.
Do not use staples, paper clips, glue or correction fluid.
Write your name, index number and tutorial class on the Answer Sheet in the spaces provided unless this has been done for you.

There are **thirty** questions on this paper. Answer **all** questions. For each question there are four possible answers **A**, **B**, **C** and **D**.

Choose the **one** you consider correct and record your choice in **soft pencil** on the separate Answer Sheet.

Read the instructions on the Answer Sheet very carefully.

Each correct answer will score one mark. A mark will not be deducted for a wrong answer.

Any rough working should be done in this booklet.

The use of an approved scientific calculator is expected, where appropriate.

This document consists of **15** printed pages and **1** blank page.

1 In an organic synthesis, a 62% yield of product is achieved.

Which conversions are consistent with the given information?

1 74 g of butan-2-ol (M_r = 74.0) $\rightarrow$ 44.64 g of butanone (M_r = 72.0)

2 72 g of butanal (M_r = 72.0) $\rightarrow$ 45.88 g of butan-1-ol (M_r = 74.0)

3 56 g of but-2-ene (M_r = 56.0) $\rightarrow$ 37.20 g of ethanoic acid (M_r = 60.0)

A 1, 2 and 3

B* 1 and 2 only

C 2 and 3 only

D 1 only

Answer B

62% yield $\Rightarrow \frac{\text{actual yield}}{\text{theoretical yield}} \times 100 = 62\%$

Option 1
$CH_3CH(OH)CH_2CH_3 \rightarrow CH_3COCH_2CH_3$ $\frac{74}{74} = 1$ mol $\quad\quad$ $\frac{44.64}{72} = 0.62$ mol
% yield = $\frac{0.62}{1} \times 100 = 62$ %
correct

Option 2
$CH_3CH_2CH_2CHO \rightarrow CH_3CH_2CH_2CH_2OH$ $\frac{72}{72} = 1$ mol $\quad\quad$ $\frac{45.88}{74} = 0.62$ mol
% yield = $\frac{0.62}{1} \times 100 = 62$ %
correct

Option 3
$CH_3CH{=}CHCH_3 \rightarrow 2CH_3COOH$ $\frac{56}{56} = 1$ mol $\quad\quad$ $\frac{37.2}{60} = 0.62$ mol
% yield = $\frac{0.62}{2} \times 100 = 31$ %
Incorrect

2 *Use of the Data Booklet is relevant to this question.*

Sodium percarbonate, ***x***(Na_2CO_3).***y***(H_2O_2) is a chemical that is used in cleaning powders. When dissolved in water, it releases hydrogen peroxide and sodium carbonate, both of which are useful cleaning agents.

A sample of 10.0 cm^3 of 0.100 mol dm^{-3} sodium percarbonate requires 20.0 cm^3 of 0.100 mol dm^{-3} of acidified KI before the end point of titration is reached.

Another identical sample releases 48.0 cm^3 of carbon dioxide at room conditions on reaction with excess acid.

What are the values of ***x*** and ***y*** respectively?

	x	***y***
A*	2	1
B	3	2
C	2	3
D	3	1

Answer A

Amount of sodium percarbonate = 10/1000 x 0.10 = 0.001 mol
As 1 mole of sodium percarbonate will produce y mole of H_2O_2 and x mole of Na_2CO_3
Amount of H_2O_2 = 0.001y mol
Amount of Na_2CO_3 = 0.001x mol

$H_2O_2 + 2H^+ + 2I^- \rightarrow I_2 + 2H_2O$
Amount of KI reacted = 20/1000 x 0.100 = 0.002 mol
Since KI: H_2O_2 is 2:1,
Amount of H_2O_2 = 0.001 mol, thus y = 1

$Na_2CO_3 + 2H^+ \rightarrow H_2O + CO_2 + 2Na^+$
Amount of carbon dioxide released = 48.0/24000 = 0.002 mol
Since Na_2CO_3: CO_2 is 1:1

Amount of Na_2CO_3 = 0.002 mol, thus x =2

3 An ion X^{2+} contains 24 protons.

What is the electronic configuration of X^{3+}?

A* $1s^2\ 2s^2\ 2p^6\ 3s^2\ 3p^6\ 3d^3$

B $1s^2\ 2s^2\ 2p^6\ 3s^2\ 3p^6\ 3d^4$

C $1s^2\ 2s^2\ 2p^6\ 3s^2\ 3p^6\ 3d^1\ 4s^2$

D $1s^2\ 2s^2\ 2p^6\ 3s^2\ 3p^6\ 3d^5\ 4s^1$

Answer A

X contains 24 electrons.

Electronic configuration of X is $1s^2\ 2s^2\ 2p^6\ 3s^2\ 3p^6\ 3d^4\ 4s^2$

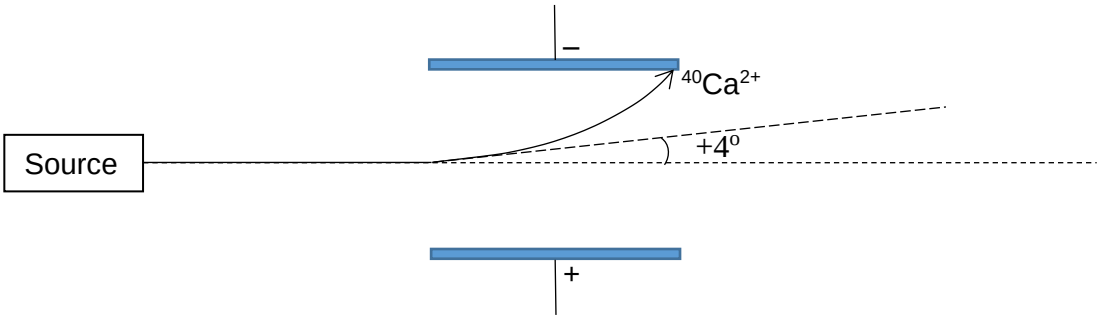
X^{2+} contains 22 electrons.

Electronic configuration is $1s^2\ 2s^2\ 2p^6\ 3s^2\ 3p^6\ 3d^4$

Loss of 1 electron from X^{2+} leads to the formation of X^{3+}.

Hence, electronic configuration is $1s^2\ 2s^2\ 2p^6\ 3s^2\ 3p^6\ 3d^3$

4 A sample of the element calcium was vaporised, ionised and passed through an electric field. It was observed that a beam of $^{40}Ca^{2+}$ particles gave an angle of deflection of +4°.



Assuming an identical set of experimental conditions, by what angle would a beam of $^{19}F^-$ particles be deflected?

A +2° **B** – 2° **C** +4° **D*** – 4°

Solution

Angle of Deflection $\propto \frac{Charge}{Mass}$

For $^{40}Ca^{2+}$, $+4° \propto \frac{+2}{40}$

and therefore for $^{19}F^-$, $\frac{-1}{19} \propto -4°$

5 *Use of Data Booklet is relevant to this question.*

X, **Y** and **Z** are isotopes of three different elements. An isotope of Argon has a mass number of 41 and the same number of neutrons in the nucleus as each of the isotopes **X**, **Y** and **Z**.

The species Ar, $\mathbf{X}^{+}$, $\mathbf{Y}^{2+}$ and $\mathbf{Z}^{3+}$ all contain the same number of electrons.

What are the mass numbers of **X**, **Y** and **Z**?

	X	**Y**	**Z**
A	42	41	40
B	40	41	42
C	44	43	42
D*	42	43	44

Solution

	$^{41}_{18}Ar$	$^{42}_{19}K^{+}$	$^{43}_{20}Ca^{2+}$	$^{44}_{21}Sc^{3+}$
No. of electrons	18	18	18	18
No. of neutrons	23	23	23	23

6 Equimolar amounts of the liquids, water and ethanol, are mixed together at 20 °C. The original intermolecular forces in the pure liquids are disrupted and weaker intermolecular forces between water and ethanol are made simultaneously.

The boiling point of water is 100 °C. The boiling point of ethanol is 78 °C.

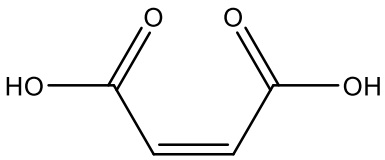
Which row is correct?

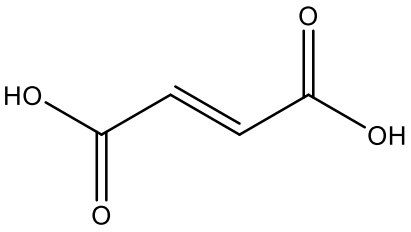
	initial temperature of **mixture**	boiling point of **mixture**
A	above 20 °C	above 78 °C
B	above 20 °C	below 78 °C
C	below 20 °C	above 100 °C
D*	below 20 °C	below 100 °C

Solution

The reaction is endothermic because weaker intermolecular forces are made.
Therefore the initial temperature of mixture is below 20 ^{o}C.
Molecules will vaporise more easily since weaker intermolecular forces are made.
Therefore the boiling point of mixture is below 100 ^{o}C.

7 The pK_a and solubility values of maleic acid and fumaric acid are as follows:





	maleic acid	fumaric acid
pK_{a1}	1.94	3.03
pK_{a2}	6.22	4.54
solubility / g per 100g water	78.8	0.49

Which statements are correct?

1 The pK_{a1} value of maleic acid is less than the pK_{a1} value of fumaric acid because the conjugate base of maleic acid can form intramolecular hydrogen bond, while that of fumaric acid cannot form such intramolecular hydrogen bond.

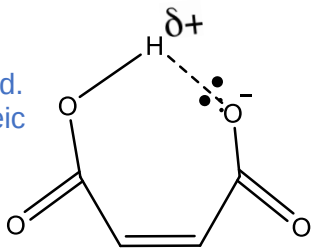
2 The pK_{a1} value of maleic acid is less than the pK_{a1} value of fumaric acid because maleic acid is much more soluble in water than fumaric acid.

3 The pK_{a2} value of maleic acid is greater than the pK_{a2} value of fumaric acid because intramolecular hydrogen bond prevents the conjugate base of maleic acid from deprotonating the second hydrogen atom.

A 1, 2 and 3 **B** 1 and 2 only **C*** 1 and 3 only **D** 2 only

Solution

Option 1 is correct:
Conjugate base of maleic acid can form intramolecular hydrogen bond. Therefore it is stable, and more readily formed than that of fumaric acid. Maleic acid is more acidic than fumaric acid.
Hence pKa_1 is lower.

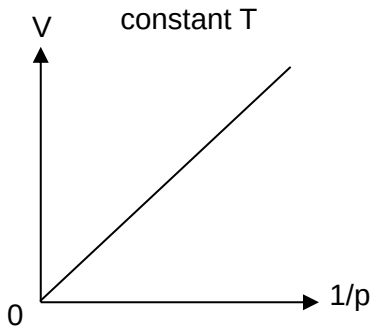


Option 3 is correct:
Conjugate base of maleic acid can form intramolecular hydrogen bond. It is stable, and not likely to lose the second hydrogen atom as H^+. Maleic acid is less acidic than fumaric acid.
Hence pKa_2 is higher.

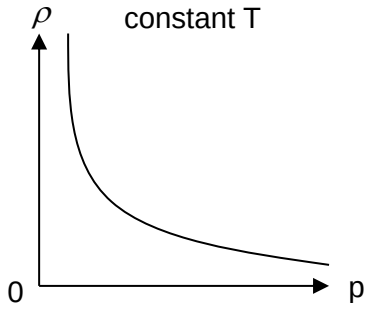
Option 2 is wrong:
Acid Strength does not depend on solubility.

8 Which diagram **does not** describe the behaviour of a fixed mass of an ideal gas?
(ρ = density of the gas, T = temperature measured in K)

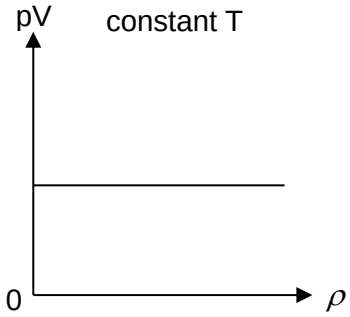
A



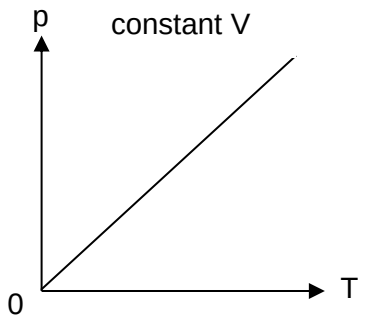
C*



B



D



Answer C

For a given mass of gas, the no. of moles of gas, n, will be constant since Mr unchanged.

pV = nRT

Option A: $V = nRT\left(\frac{1}{P}\right)$

V = constant x $\left(\frac{1}{P}\right)$, at constant T for a given mass of gas.

Hence, $V \propto \left(\frac{1}{P}\right)$

Option B: pV = nRT

pV = constant, at constant T for given mass of gas, regardless of changes in P, V or ρ

Option C: $pV = nRT = \frac{m}{M_r}RT$

$\rho = \frac{m}{V} = \frac{M_r}{RT}(P)$ = constant x (P), at constant T for a given mass of gas.

Hence, $\rho \propto P$ and it should be a Y = mX + C linear graph, passing through origin.

Option D:

$P = \frac{nR}{V}(T)$

P= constant x (T), at constant V for a given mass of gas.

Hence, $P \propto T$

9 Which equation corresponds to the enthalpy change stated?

A	$H_2O(l) \rightarrow 2H(g) + O(g)$	$\Delta H = 2 \times$ Bond Energy (O–H)
B*	$\frac{1}{2}\ Cl_2(g) \rightarrow Cl^-(aq)$	$\Delta H_{formation}(Cl^-(aq))$
C	$CO(g) + \frac{1}{2}\ O_2(g) \rightarrow CO_2(g)$	$\Delta H_{combustion}(CO_2(g))$
D	$Na^+(g) \rightarrow Na^+(aq)$	$\Delta H_{solution}(Na^+(g))$

Solution

Option A is wrong:
It should be: $H_2O(g) \rightarrow 2H(g) + O(g)$

Option B is correct:
Enthalpy change when one mole of the substance is formed from its elements.

Option C is wrong:
It should be: $\Delta H_{combustion}(CO(g))$

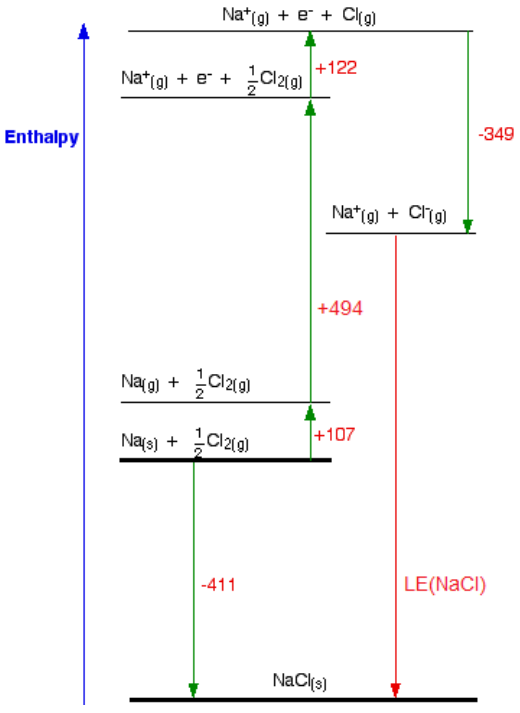
Option D is wrong:
It should be: $\Delta H_{hydration}(Na^+(g))$

10 Given the following data in kJ mol^{-1}

enthalpy change of atomisation of Na(s)	+107
electron affinity of C*l* atom	–349
enthalpy change of formation of NaC*l*(s)	–411
enthalpy change of atomisation of C*l*(g)	+122
1st IE of Na atom	+494

What is the lattice energy of NaC*l*(s) in kJ mol^{-1}?

A* –785 **B** –907 **C** –1269 **D** –1483



By Hess' Law

LE(NaCl(s))

= –411 – [+107 + 494 + 122 + (–349)]

= –785 kJ mol^{-1}

11 Trouton's rule states that the entropy change of vaporisation is about +85 J K^{-1} mol^{-1} for various kinds of liquids.

Propan-1-ol boils at 371 K and its enthalpy change of vaporisation is +47 kJ mol^{-1}.

Which statement is correct?

A Entropy change of vaporisation of propan-1-ol cannot be calculated because there is no data on Gibbs free energy change of vaporisation of propan-1-ol.

B Entropy change of vaporisation of propan-1-ol is +85 J mol^{-1} K^{-1}.

C* Entropy change of vaporisation of propan-1-ol is +127 J mol^{-1} K^{-1} which is more positive than +85 J mol^{-1} K^{-1} because of the strong hydrogen bonds between molecules.

D Entropy change of vaporisation of propan-1-ol is +127 J mol^{-1} K^{-1} which is more positive than +85 J mol^{-1} K^{-1} because of the weak instantaneous dipole induced dipole attraction between molecules.

Solution

Boiling is an equilibrium process between $H_2O(l)$ and $H_2O(g)$.

$\Delta G = 0$

$\Delta H - T\,\Delta S = 0$

$47{,}000 - 371 \times \Delta S = 0$

$\Delta S = +127$ J mol^{-1} K^{-1}

Option C is correct. Most gases have the same entropy values. Having a more positive ΔS value means that propan-1-ol has lower entropy value in the liquid state (or more orderly). This is due to the ability of propan-1-ol molecules being able to form hydrogen bonds between molecules.

12 Ethyl ethanoate undergoes a slow acid-catalysed hydrolysis in water.

$$CH_3CO_2CH_2CH_3 + H_2O \xrightarrow{H^+} CH_3CO_2H + CH_3CH_2OH$$

The rate equation is found to be

$$\text{rate} = k[CH_3CO_2CH_2CH_3][H^+]$$

When 0.1 mol dm^{-3} of HC*l* is reacted with 0.2 mol dm^{-3} of ethyl ethanoate, the half-life was found to be 62 min.

Another reaction was carried out with 0.2 mol dm^{-3} of HC*l* and 0.2 mol dm^{-3} of ethyl ethanoate.

How long does it take for the concentration of ethyl ethanoate to fall to 0.025 mol dm^{-3}?

A 31 min **B** 62 min **C*** 93 min **D** 124 min

Answer C

When [HC*l*] = [H^+] = 0.1 mol dm^{-3},
$t_{½}$ = 62 min.

When [HC*l*] = [H^+] = 0.2 mol dm^{-3} (increased by two times),
$t_{½}$ = 31 min.

For [$CH_3CO_2CH_2CH_3$] to fall to 0.025 mol dm^{-3}, three $t_{½}$ are required.

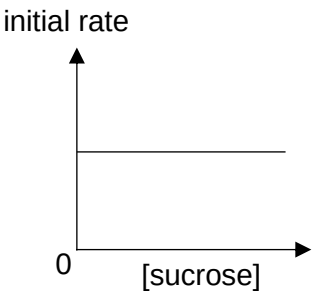
0.2 → 0.1 → 0.05 → 0.025

Time taken = 3 x 31 = 93 min

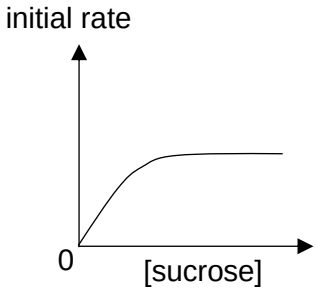
13 Sucrase is a digestive enzyme that catalyses the hydrolysis of sucrose to fructose and glucose. In an experiment, the amount of sucrase and the temperature of the reaction mixture is kept constant.

Which graph is correct?

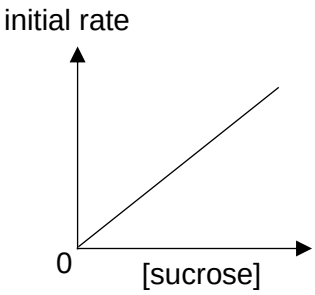
A



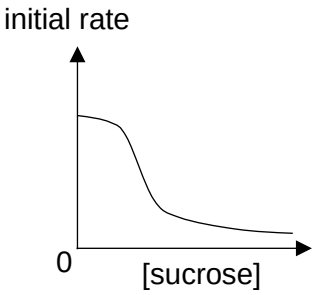
C*



B



D



Solution

Option C is correct.
At low [sucrose], the enzymes are not saturated with sucrose substrate molecules. Increasing [sucrose] will increase the rate. Reaction is first order at low [sucrose].
At high [sucrose], the enzymes are saturated with sucrose substrate molecules. Increasing [sucrose] further will not increase the rate. Reaction is zero order at high [sucrose].

Option A is wrong. It is a graph for zero-order reaction.
Option B is wrong. It is a graph for first-order reaction.
Option D is wrong. It is a graph for autocatalytic reaction.

14 Highly toxic disulfur decafluoride, S_2F_{10}, decomposes by a free-radical process.

$$S_2F_{10}(g) \rightleftharpoons SF_4(g) + SF_6(g)$$

Some S_2F_{10} was placed in a 2.0 dm^3 flask and heated to 110 ^oC to reach equilibrium. The equilibrium concentration of S_2F_{10} was found to be 0.6 mol dm^{-3}. More S_2F_{10} was then added and the new equilibrium concentration of S_2F_{10} was 2.6 mol dm^{-3}.

What is the change in concentration of S_2F_{10} that occurred in terms of the equilibrium constant, K_c, of the decomposition reaction when more S_2F_{10} was added?

A $(0.6K_c)^{0.5} - (2.6K_c)^{0.5}$

B* $(2.6K_c)^{0.5} - (0.6K_c)^{0.5}$

C $(2.4K_c)^{0.5} - (10.4K_c)^{0.5}$

D $(10.4K_c)^{0.5} - (2.4K_c)^{0.5}$

Answer B

Calculating the equilibrium $[SF_4]$ and $[SF_6]$ when the equilibrium $[S_2F_{10}]$ = 0.6 mol dm^{-3}

Let the equilibrium $[SF_4]$ = a

Equilibrium $[SF_6]$ = equilibrium $[SF_4]$ = a

$$K_c = \frac{a^2}{0.6}$$

a = $(0.6\ K_c)^{0.5}$

Calculating the equilibrium $[SF_4]$ and $[SF_6]$ when more S_2F_{10} was added and the equilibrium $[S_2F_{10}]$ = 2.6 mol dm^{-3}

Let the equilibrium $[SF_4]$ = b

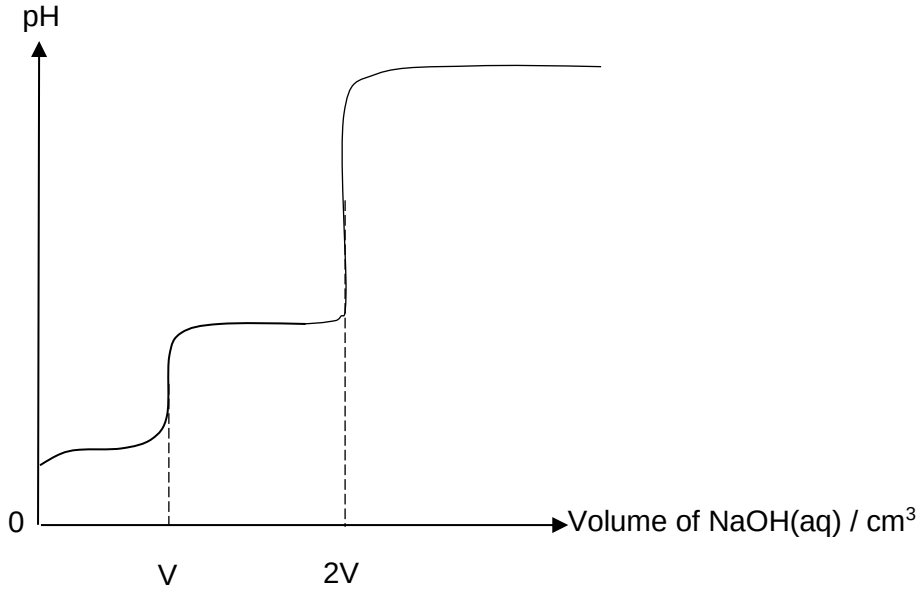
Equilibrium $[SF_6]$ = equilibrium $[SF_4]$ = b

$$K_c = \frac{b^2}{2.6}$$

b = $(2.6\ K_c)^{0.5}$
$[S_2F_{10}]$ reacted = additional $[SF_4]$ produced = b – a = $(2.6\ K_c)^{0.5} - (0.6\ K_c)^{0.5}$

15 Ethanedioic acid has these pK_a values: pK_{a1} = 1.25 and pK_{a2} = 4.14.

The titration curve below shows how the pH changes when 0.10 mol dm^{-3} aqueous sodium hydroxide is added to 25.0 cm^3 of 0.10 mol dm^{-3} ethanedioic acid.



Which statement is correct?

A The pH of ethanedioic acid is 1.03 before NaOH(aq) is added.

B The pH of solution mixture is 1.15 when 12.50 cm^3 of NaOH(aq) is added,.

C* The pH of solution mixture is 3.54 when 30.00 cm^3 of NaOH(aq) is added.

D Methyl orange can be used as pH indicator for the second endpoint.

Solution

Option A is wrong.

	HOOC–COOH(aq)	⇌	HOOC–COO$^-$(aq)	+	H$^+$(aq)
Initial	0.10		0		0
Change	–x		+x		+x
Eqm	0.10 – x		x		x

$K_{a1} = x^2 / (0.10 – x)$
$x = 0.0750$
$[H^+] = 0.0750$
$pH = –\log [H^+] = 1.125$

Option B is wrong.
At Max Buffer Capacity, $pH = pK_{a1} = 1.25$

Option C is correct.
Amount of $^-$OOC–COO$^-$ produced = Amount of HOOC–COO$^-$ reacted
= (30.00 – 25.00) ÷ 1000 x 0.10 = 0.0005 mol
Remaining Amount of HOOC–COO$^-$ = 0.0025 – 0.0005 = 0.0020 mol
Acid Buffer: $pH = pK_{a2} + \log [salt] / [acid] = 4.14 + \log (0.0005 / 0.055) / (0.0020 / 0.055) = 3.54$

Option D is wrong.
Sharp rise in pH from about 4.3 at second endpoint.
Working pH range of methyl orange: 3.1 < pH < 4.4
pH range of methyl orange does not fall within the pH change at second endpoint.

16 The numerical value of solubility product of silver chromate(VI), Ag_2CrO_4 is 2.5×10^{-22} at 25 °C.

Which statement is correct?

A The units of solubility product of silver chromate(VI) are $mol^2\ dm^{-6}$.

B* The solubility of silver chromate(VI) is 3.97×10^{-8} mol dm^{-3}.

C Addition of aqueous sodium hydroxide will increase the solubility product of silver chromate(VI).

D Addition of aqueous sodium hydroxide will decrease the solubility of silver chromate(VI).

Solution

$Ag_2CrO_4(s) \rightleftharpoons 2Ag^+(aq) + CrO_4^{2-}(aq)$

$K_{sp} = 2.5 \times 10^{-22}\ mol^3\ dm^{-9}$
$K_{sp} = [Ag^+(aq)]^2\ [CrO_4^{2-}(aq)]$
$(2x)^2(x) = 2.5 \times 10^{-22}$
$x = 3.97 \times 10^{-8}$ mol dm^{-3}
Option B is correct.

Option A is wrong.

Option C is wrong. Ksp only depends on Temperature (if $\Delta H \neq 0$)

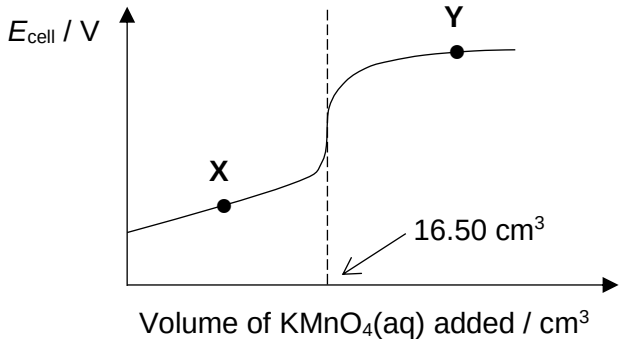
Option D is wrong.
$Ag^+(aq) + OH^-(aq) \rightarrow AgOH(s)$
[Ag+] will decrease.
This causes the equilibrium to shift to the right: $Ag_2CrO_4(s) \rightleftharpoons 2Ag^+(aq) + CrO_4^{2-}(aq)$
Hence more $Ag_2CrO_4(s)$ dissolves.

17 *Use of Data Booklet is relevant to this question.*

Iron(II) salts are often used as a dietary supplement to help cure anaemia. A pill was dissolved in 10 cm^3 of dilute sulfuric acid and titrated against 0.02 mol dm^{-3} $KMnO_4(aq)$.

$$MnO_4^-(aq) + 8H^+(aq) + 5Fe^{2+}(aq) \rightarrow Mn^{2+}(aq) + 4H_2O(l) + 5Fe^{3+}(aq)$$

The E_{cell} of the solution mixture was measured against a standard hydrogen electrode and the following graph was obtained.



Which statements are correct?

1 At point **X**, E_{cell} = +0.77 V.

2 At point **Y**, E_{cell} = +1.52 V.

3 The pill contains 1.65×10^{-3} mole of Fe^{2+}.

A* 1, 2 and 3 **B** 1 and 2 only **C** 2 and 3 only **D** 3 only

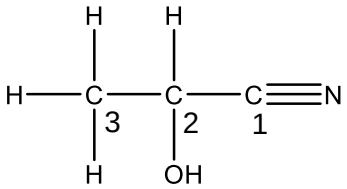
Solution

Option 1 is correct.
At point X, there are approximately equal concentrations of $Fe^{2+}(aq)$ and $Fe^{3+}(aq)$.
They are at equilibrium.
$Fe^{3+}(aq) + e \rightleftharpoons Fe^{2+}(aq)$

Option 2 is correct.
At point Y, there are approximately equal concentrations of $Mn^{2+}(aq)$ and $MnO_4^-(aq)$.
They are at equilibrium.
$MnO_4^-(aq) + 8H^+(aq) + 5e \rightleftharpoons Mn^{2+}(aq) + 4H_2O(l)$

Option 3 is correct.
Amount of MnO_4^- = (0.02)(16.50/1000) = 3.3×10^{-4} mol
Amount of Fe^{2+} = $5 \times 3.3 \times 10^{-4} = 1.65 \times 10^{-3}$ mol

18 2-hydroxypropanenitrile has the following structure.

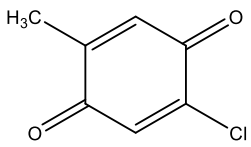


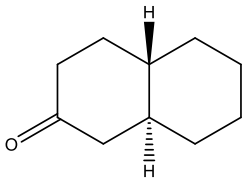
Which row correctly describes the bonding and hybridisation in the molecule?

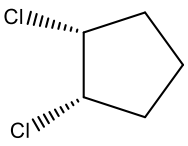
	number of π bonds	hybridisation of C1 atom	hybridisation of N atom	hybridisation of O atom
A*	2	sp	sp	sp^3
B	2	sp	sp^3	sp^2
C	4	sp^2	sp^2	sp^2
D	4	sp^2	sp^3	sp

Solution
Shape around C1 atom is LINEAR. Hence it is sp hybridised.
Shape around N atom is LINEAR (considering the lone pair on N as well). Hence it is sp hybridised.
Shape around O atom is TETRAHEDRAL (considering the two lone pairs of electrons on O as well). Hence it is sp^3 hybridised.

19 Which of the following molecules are meso compounds?

1 

2 

3 

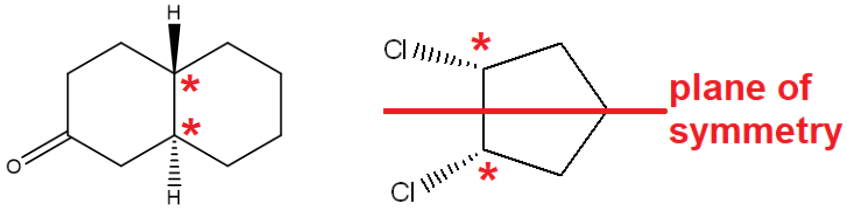
A 1, 2 and 3 **B** 1 and 3 only **C** 2 only **D*** 3 only

Solution

Option 1 does not have any chiral carbon.

Option 2 has two chiral carbons and no plane of symmetry.
Bulk sample is optically active.
It is not meso compound.

Option 3 has two chiral carbons and also plane of symmetry.
Bulk sample is not optically active.
It is a meso compound.



20 CH_3F and Cl_2 are mixed together in the presence of sunlight.

Which statements are correct?

1 F● free radicals are produced.
2 Hydrogen gas is produced.
3 The reaction involves homolytic fission and σ bond formation.

A 1, 2 and 3 **B** 1 and 2 only **C** 2 and 3 only **D*** 3 only

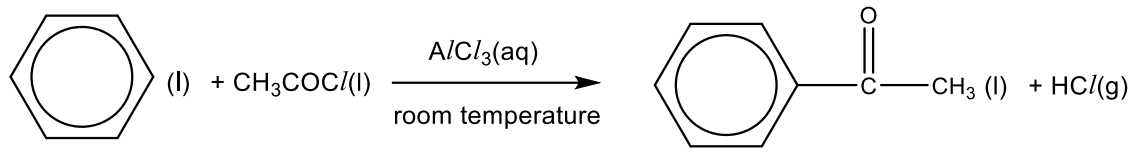
Solution

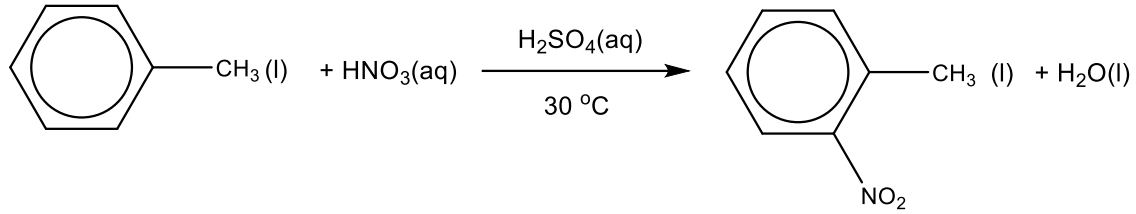
Option 1 is wrong.
C–F bond is strong and will not be broken by sunlight.

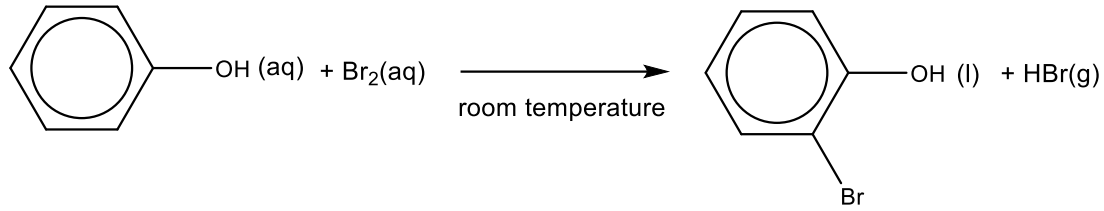
Option 2 is wrong.
H● radicals are not formed during propagation. Hence H_2 gas cannot be produced.

Option 3 is correct.

21 Which of the following transformation has a set of conditions that is **not** correct?

1 

2 

3 

A* 1, 2 and 3 **B** 1 and 3 only **C** 2 and 3 only **D** 3 only

Solution

Option 1 is wrong.
For this reaction to occur: $AlCl_3 + CH_3COCl \rightarrow CH_3CO^+ + AlCl_4^-$
Water must not be present.
If not, $AlCl_3$ will dissolve in water to give $Al^{3+}(aq)$ and $Cl^-(aq)$ ions.
There is no $AlCl_3$ halogen carrier anymore.

Option 2 is wrong.
For this reaction to occur: $HNO_3 + 2H_2SO_4 \rightarrow NO_2^+ + H_3O^+ + 2HSO_4^-$
Water must not be present
If not $H_2SO_4 \rightarrow 2H^+ + SO_4^{2-}$
$[NO_2^+]$ will be low.

Option 3 is wrong.
$Br_2(aq)$ leads to tri-substitution on phenol.
For mono-substitution on phenol, Br_2 (in CCl_4) should be used.

22 A student added aqueous silver nitrate to bromoethane, bromoethene and bromobenzene.

Which statements are correct?

1 White precipitate forms for bromoethane.

2 Cream precipitate forms for bromoethene.

3 No precipitate forms for bromobenzene.

A 1 only **B** 2 only **C*** 3 only **D** 2 and 3 only

Solution

Option 1 is wrong.

$CH_3CH_2Br + H_2O \rightarrow CH_3CH_2OH + H^+ + Br^-$

$Ag^+ + Br^- \rightarrow AgBr$ (cream ppt)

Option 1 is wrong.

$CH_2=CHBr + H_2O \rightarrow$ No reaction

Partial double bond overlap for C–Br bond with C=C bond.

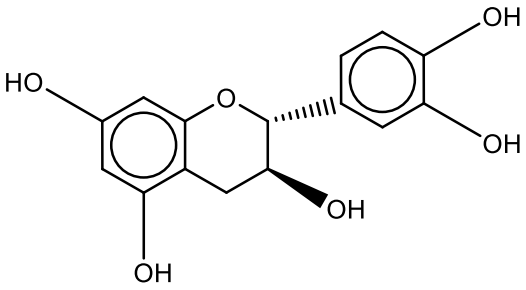
Stronger C–Br bond does not break. No ppt formed.

Option 1 is correct.

Partial double bond overlap for C–Br bond with π system of delocalised electrons in benzene ring.

Stronger C–Br bond does not break. No ppt formed.

23 Catechin is an antioxidant found in green tea, chocolate and peaches.



Catechin

The C–O–C bond is inert.

Which statement is correct?

A 1 mol of catechin reacts with 5 mol of aqueous sodium hydroxide.

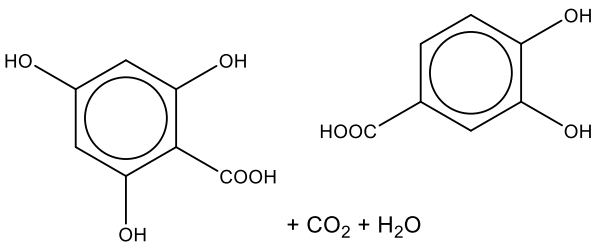
B 1 mol of catechin reacts with sodium to produce 5 mol of hydrogen gas.

C* 1 mol of catechin reacts with 5 mol of aqueous bromine.

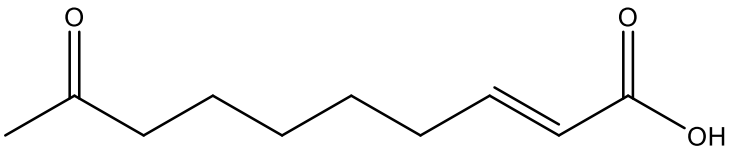
D A ketone functional group is produced when catechin is oxidised by hot acidified $KMnO_4(aq)$.

Solution

Option 1 is wrong.
4 moles of phenol react with 4 moles of NaOH(aq).
Alcohol does not react with NaOH(aq).
Option 2 is wrong.
4 moles of phenol and 1 mole of alcohol react with sodium to produce 2.5 moles of $H_2(g)$.
Option 3 is correct.
Option 4 is wrong.



24 Queen honeybee secretes "queen substance" that is eaten by worker bees. This prevents them from producing rival queen bees in the same colony. The "queen substance" is 9-oxo-2-decenoic acid.



9-oxo-2-decenoic acid

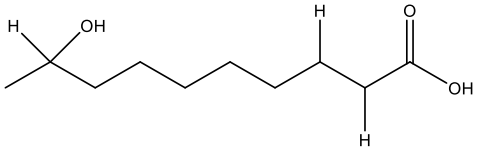
What is the number of hydrogen atoms added per molecule of "queen substance" for the following reactions?

	reducing agent	number of hydrogen atoms added per molecule of queen substance
1	H_2, Pt	6
2	$LiAlH_4$ in dry ether	4
3	$NaBH_4$ in methanol	2

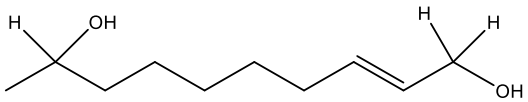
A 1, 2 and 3 **B*** 2 and 3 only **C** 2 only **D** 1 only

Solution

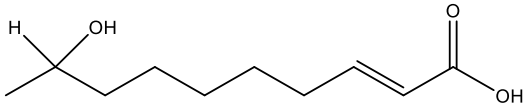
Option 1 is wrong.



Option 2 is correct.



Option 3 is correct.



25 Which of the following reagents and conditions are appropriate for making methanoic acid from methanol?

A $K_2Cr_2O_7$(aq), dilute H_2SO_4(aq), heat with distillation

B* $K_2Cr_2O_7$(aq), dilute H_2SO_4(aq), heat under reflux

C $K_2Cr_2O_7$(aq), dilute HC*l*(aq), heat under reflux

D $KMnO_4$(aq), dilute H_2SO_4(aq), heat under reflux

Solution

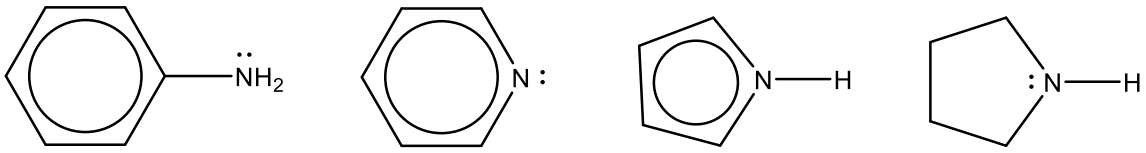
Option A is wrong.
$CH_3OH + [O] \rightarrow HCHO + H_2O$
Since HCHO has lower boiling point than CH_3OH, HCHO will be distilled over before further oxidation is possible.

Option B is correct.
$CH_3OH + [O] \rightarrow HCHO + H_2O$
$HCHO + [O] \rightarrow HCOOH$

Option C is wrong.
HCl should not be used because it will be oxidised to Cl_2 by hot $K_2Cr_2O_7$(aq).

Option D is wrong.
$CH_3OH + [O] \rightarrow HCHO + H_2O$
$HCHO + [O] \rightarrow HCOOH$
HCOOH will be further oxidised by hot $KMnO_4$(aq) to give CO_2 and H_2O.
$HCOOH + [O] \rightarrow H_2CO_3 \rightarrow CO_2 + H_2O$

26 Consider the following compounds.



phenylamine pyridine pyrrole pyrrolidine

Which of the following shows the correct order of decreasing pK_b value?

A* pyrrole > phenylamine > pyridine > pyrrolidine

B pyrrolidine > pyridine > phenylamine > pyrrole

C pyrrole > phenylamine > pyrrolidine > pyridine

D phenylamine > pyridine > pyrrole > pyrrolidine

Solution

HINT: Lone pair of electrons is indicated on N atom.

Huckel's rule says that (4n + 2) electrons should be in the ring, where n = 1, 2, 3 …

Pyrrole is least basic. N atom already has 3 bonds. Its lone pair of electrons is delocalised into the ring. It is not available for protonation.

Pyrrolidine is most basic. N atom has 3 bonds. Its lone pair of electrons is NOT delocalised into any ring. It is available for protonation. In addition, it is a secondary amine where two alkyl groups donate electrons to N atom, increasing the availability of lone pair for protonation.

Phenylamine is second least basic. The lone pair of electrons on N atom is partially delocalised into the benzene ring.

Pyridine is second most basic. N already has three bonds in the ring, with one electron delocalised into the ring. The lone pair of electrons on N atom is not part of the ring. It is available for protonation.

27 A particular section of keratin polypeptide was digested with two enzymes.

The first enzyme digests at the carboxyl end of leucine and yields the following peptides:

glu-ala
val-leu
glu-asp-thr-leu
ala-glu-leu

The second enzyme digests at the carboxyl end of glutamic acid and yields the following peptides:

ala
val-leu-glu
asp-thr-leu-ala-glu
leu-glu

What is the primary structure in this section of polypeptide chain?

A ala-glu-leu-glu-asp-thr-leu-val-leu-glu-ala

B* val-leu-glu-asp-thr-leu-ala-glu-leu-glu-ala

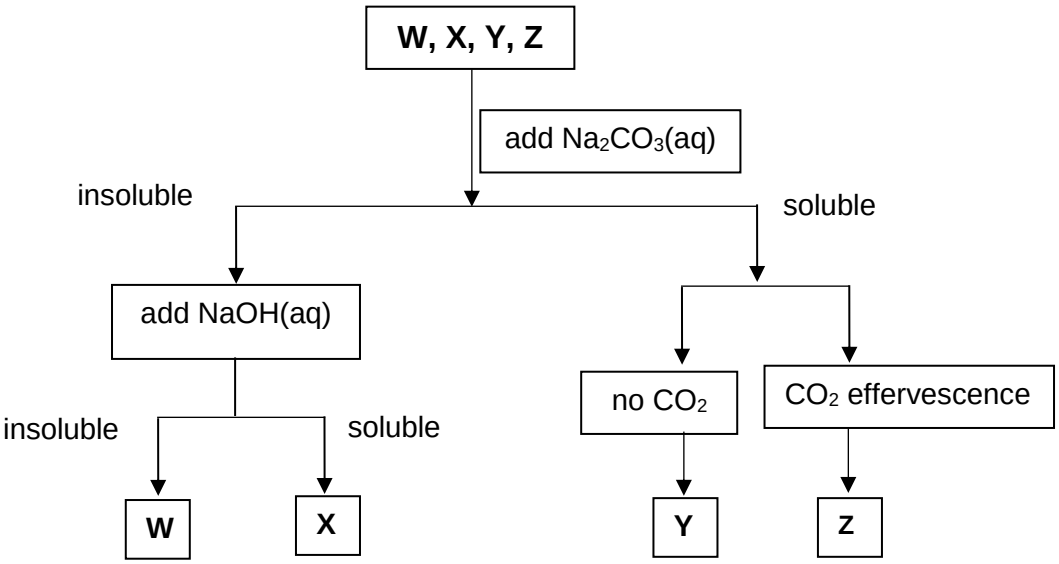
C glu-asp-thr-leu-ala-glu-leu-val-leu-glu-ala

D glu-ala-ala-glu-leu-glu-asp-thr-leu-val-leu

Solution

val-leu
val-leu-glu
glu-asp-thr-leu
asp-thr-leu-ala-glu
ala-glu-leu
leu-glu
glu-ala
ala
val-leu-glu-asp-thr-leu-ala-glu-leu-glu-ala

28 The labels of four containers containing NaCl, $AlCl_3$, Al_2O_3 and SiO_2 were detached from the containers. The compounds could be identified using the following flowchart.



What are **W**, **X**, **Y** and **Z**?

	W	**X**	**Y**	**Z**
A*	SiO_2	Al_2O_3	NaCl	$AlCl_3$
B	Al_2O_3	SiO_2	NaCl	$AlCl_3$
C	NaCl	$AlCl_3$	SiO_2	Al_2O_3
D	SiO_2	Al_2O_3	$AlCl_3$	NaCl

Solution

SiO_2 and Al_2O_3 does not dissolve in water. They do not react with Na_2CO_3(aq).

NaCl(s) → Na^+(aq) + Cl^-(aq)
Na^+(aq) is neutral. It is not acidic to react with Na_2CO_3(aq).

$AlCl_3$(s) → Al^{3+}(aq) + $3Cl^-$(aq)
Al^{3+}(aq) is acidic with pH about 3.
$[Al(H_2O)_6]^{3+}$(aq) → $[Al(H_2O)_5(OH)]^{2+}$(aq) + H^+(aq)
It is acidic enough to react with Na_2CO_3(aq).
$2H^+$(aq) + CO_3^{2-}(aq) → H_2CO_3(aq) → H_2O(l) + CO_2(g)

SiO_2 does not react with NaOH(aq). It reacts with fused NaOH.
With fused NaOH: $SiO_2 + 2NaOH \rightarrow Na_2SiO_3 + H_2O$

Al_2O_3(s) + 2NaOH(aq) + $3H_2O$(l) → $2Na^+$(aq) + $2Al(OH)_4^-$(aq)
Note: Al_2O_3(s) also reacts with HCl(aq). It is amphoteric oxide.

29 Which of the following statements about Group 2 elements is **not** correct?

A The reactivity with cold water increases down the group.

B The thermal stability of the carbonate increases down the group.

C* The solubility of the hydroxide decreases down the group.

D The solubility of the sulfate decreases down the group.

Solution

Option A is correct.
The sea of delocalised electrons is further away from the nuclei of metal cations. There is weaker electrostatic attraction. Less energy is needed to remove these outermost electrons. Metals are more reducing down the group.

Option B is correct.
Polarising Power of Cation $\alpha \frac{Charge}{Size\ of\ Cation}$
Down the group, the cation becomes larger. Polarising power becomes weaker. It is harder to polarise and weaken the C–O bonds in CO_3^{2-} ion. The thermal stability of carbonate increases down the group.

Option C is wrong.
$\Delta H_{solution} = -LE + \Delta H_{hydration}$
Down the group, the change in LE magnitude is less than the change in $\Delta H_{hydration}$. Hence $\Delta H_{solution}$ is more negative down the group. The solubility of the hydroxide increases down the group
Note: This is the opposite of sulfates. The solubility of the sulfate decreases down the group.

Option D is correct.

30 A mixture of two halogens was reacted with excess aqueous sodium thiosulfate. The resulting solution was colourless. When excess aqueous barium nitrate was added, precipitate **X** was formed.

Precipitate **X** was then filtered off and the filtrate was treated with excess aqueous silver nitrate. Some precipitates were formed and then filtered off. Excess dilute aqueous ammonia was added to wash this residue. The remaining residue was precipitate **Y** that dissolved in excess concentrated ammonia. The filtrate was treated with excess dilute nitric acid to give precipitate **Z**.

What are **X**, **Y** and **Z**?

	X	**Y**	**Z**
A	BaS_4O_6	AgI	AgBr
B	BaS_2O_3	AgBr	AgCl
C	$BaSO_4$	AgI	AgBr
D*	$BaSO_4$	AgBr	AgCl

Solution

When $S_2O_3^{2-}(aq)$ is added:

$4Br_2 + S_2O_3^{2-} + 5H_2O \rightarrow 8Br^- + 2SO_4^{2-} + 10H^+$

$I_2 + 2S_2O_3^{2-} \rightarrow 2I^- + S_4O_6^{2-}$

$Ba^{2+}(aq) + SO_4^{2-}(aq) \rightarrow BaSO_4(s)$

white ppt **X**

When $AgNO_3(aq)$ is added:

$Ag^+(aq) + Br^-(aq) \rightarrow AgBr(s)$

cream ppt

$Ag^+(aq) + Cl^-(aq) \rightarrow AgCl(s)$

white ppt

When dilute $NH_3(aq)$ is added to wash these precipitates:

$AgCl(s) \rightarrow Ag^+(aq) + Cl^-(aq)$

White ppt dissolves.

$Ag^+(aq) + 2NH_3(aq) \rightarrow Ag(NH_3)_2^+(aq)$

Note: AgBr(s) does not dissolve in dilute $NH_3(aq)$. It dissolves in concentrated $NH_3(aq)$.

When dilute $HNO_3(aq)$ is added to the filtrate:

$H^+(aq) + NH_3(aq) \rightarrow NH_4^+(aq)$

$Ag(NH_3)_2^+(aq) \rightarrow Ag^+(aq) + 2NH_3(aq)$

$Ag^+(aq) + Cl^-(aq) \rightarrow AgCl(s)$

white ppt

1	2	3	4	5	6	7	8	9	10
B	A	A	D	D	D	C	C	B	A
11	12	13	14	15	16	17	18	19	20
C	C	C	B	C	B	A	A	D	D
21	22	23	24	25	26	27	28	29	30
A	C	C	B	B	A	B	A	C	D

A	B	C	D
8	7	9	6