NATIONAL JUNIOR COLLEGE
SH2 PRELIMINARY EXAMINATION
Higher 2

CANDIDATE NAME			
SUBJECT CLASS		REGISTRATION NUMBER	

CHEMISTRY
Paper 1 Multiple Choice

9729/01
15 September 2021
1 hour

Additional Materials: Optical Answer Sheet
Data Booklet

READ THESE INSTRUCTIONS FIRST
Write in soft pencil.
Do not use staples, paper clips, highlighters, glue or correction fluid.
Write your name, subject class and registration number 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.

Instructions on how to fill in the Optical Mark Sheet
Shade the index number in a 5 digit format on the optical mark sheet:
1st digit and the last 4 digits of the Registration Number.

Example:

Student	Examples of Registration No.	Shade:
	2005648	25648

This document consists of **12** printed pages.

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1 A sample of element sulfur contains four isotopes of the following composition.

relative isotopic mass	relative abundance
32	95.02
33	0.76
34	4.20
36	0.02

What is the relative atomic mass of sulfur in this sample?

A 32.07 **B** 32.08 **C** 32.09 **D** 32.10

2 When 15 cm^3 of a gaseous organic compound were completely burnt in an excess of oxygen, 30 cm^3 of carbon dioxide and 15 cm^3 of nitrogen were formed, all volumes being measured at the same temperature and pressure.

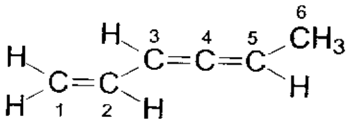
Which could be the formula of the organic compound?

A $C_2H_4N_2$ **B** C_2H_7NO **C** C_3H_7NO **D** $C_3H_6N_2$

3 Which ion has less electrons than neutrons and less neutrons than protons?

	ion	neutrons	nucleons
A	A^-	18	37
B	B^{2+}	17	34
C	C^{3+}	16	33
D	D^{3-}	16	31

4 Covalent bonds are formed by orbitals overlap.



Which statement does **not** describe the molecule above?

A The σ bond between C1–C2 is formed by $2sp^2$–$2sp^2$ overlap.

B The σ bond between C2–C3 is stronger than that between C5–C6.

C The π bond between C4–C5 is formed by 2sp–$2sp^2$ overlap.

D The σ bond between C6–H is formed by $2sp^3$–1s overlap.

5 Which options contain a polar and a non-polar molecule?

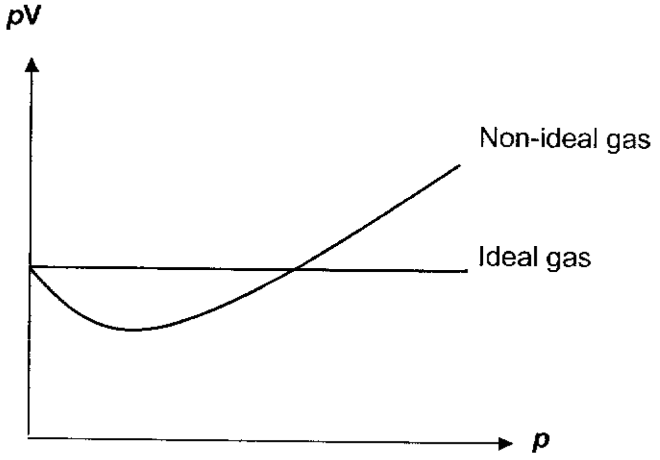
1 CO_2, H_2O

2 SO_2, PCl_5

3 CH_2Cl_2 , $SiCl_4$

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

6 The value of *p*V is plotted against *p* for two gases, an ideal gas and a non-ideal gas, where *p* is the pressure and V is the volume of the gas.



Which gas shows the greatest deviation from ideal gas behaviour at 200 °C?

A CO_2 **B** Cl_2 **C** CH_3OH **D** N_2H_4

7 Astatine is an element in Group 17. Which statements are correct?

1 Silver astatide is insoluble in aqueous ammonia.

2 Hydrogen astatide is less stable to heat than hydrogen iodide.

3 Astatine is more electronegative than iodine.

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

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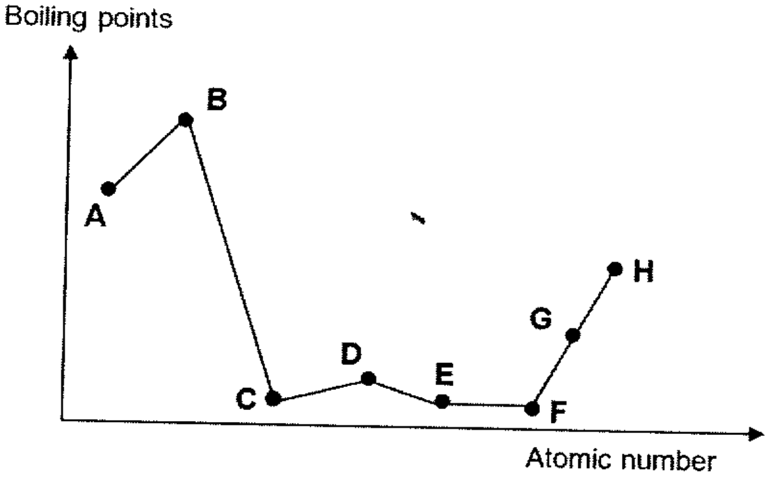
8 The graph below shows the variation in the boiling point for 8 consecutive elements in the Periodic Table, all with atomic number ≤ 20.



What can be deduced from the graph?

A The ions of **A** and **E** are isoelectronic.

B The chlorides become less acidic from **A** to **C**.

C When the oxide of **D** is added to water, the resulting solution has a pH greater than 7

D The oxide of **A** reacts with excess aqueous sodium hydroxide to form a soluble complex.

9 Given the following data:

Lattice energy of magnesium chloride	-2526 kJ mol^{-1}
Standard enthalpy change of hydration of chloride	-384 kJ mol^{-1}
Standard enthalpy change of hydration of magnesium	-1890 kJ mol^{-1}

What would be the change in temperature measured when 0.49 g of magnesium chloride was dissolved in 50 g of water?
[Molar mass of $MgCl_2$ = 95.3 g mol^{-1}]

A − 6.2 °C **B** − 3.3 °C **C** + 3.3 °C **D** + 6.2 °C

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10 Combustion of carbon monoxide to form carbon dioxide is an exothermic reaction.

What can be deduced from this information?

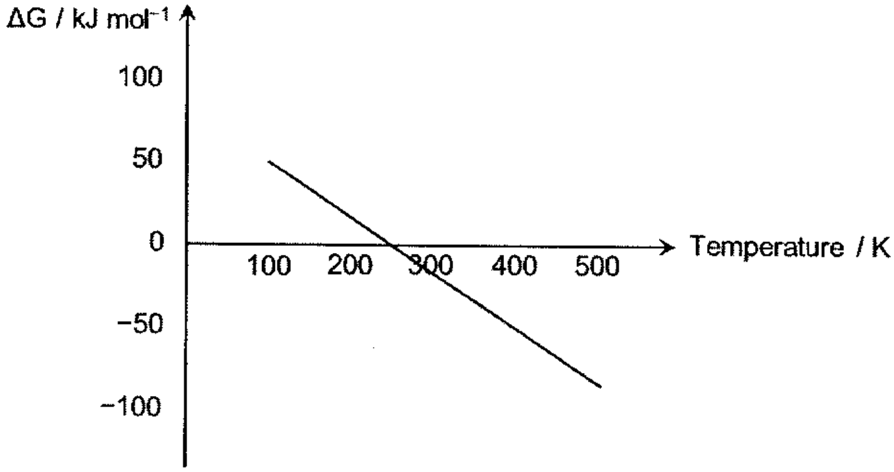
1 CO_2 is more stable than CO.

2 The standard enthalpy change of formation of carbon dioxide is more exothermic than the standard enthalpy change of formation of carbon monoxide.

3 Combustion of CO has a low activation energy.

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

11 What can be concluded about the values of ΔH and ΔS from this graph?



	ΔH	ΔS
A	positive	positive
B	positive	negative
C	negative	positive
D	negative	negative

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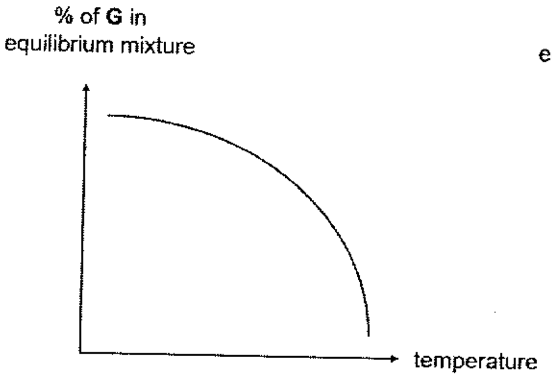
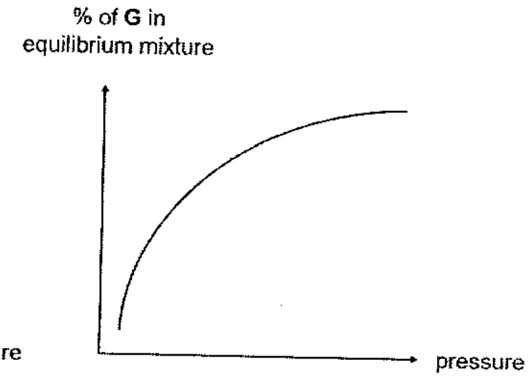
12 Compound **G** is formed during a reaction involving only gaseous particles.
The graphs below show how the percentage of compound **G** at equilibrium varies with temperature and pressure.





Which equation represents the formation of compound **G**?

	equation	ΔH
A	$E(g) + 3F(g) \rightleftharpoons 2G(g)$	negative
B	$2E(g) \rightleftharpoons F(g) + 2G(g)$	positive
C	$4D(g) + 3E(g) \rightleftharpoons 2F(g) + 6G(g)$	negative
D	$E(g) + F(g) \rightleftharpoons 2G(g)$	positive

13 Which reactions show NH_3 behaving as a Lewis base?

1 $HNO_3 + NH_3 \longrightarrow NH_4NO_3$

2 $2NH_3 \longrightarrow NH_2^- + NH_4^+$

3 $BH_3 + NH_3 \longrightarrow BH_3NH_3$

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

14 The auto-ionisation of H_2O is an endothermic process.

$$H_2O(l) \rightleftharpoons H^+(aq) + OH^-(aq) \qquad K_w = 1.0 \times 10^{-14} \text{ at } 25\ ^\circ C$$

Which option is correct about water at 60 °C?

A $pH < 7$ **B** $pH = 7$ **C** $[H^+] > [OH^-]$ **D** $[H^+] < [OH^-]$

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15 A 1 dm^3 solution contains 2×10^{-4} mol dm^{-3} each of magnesium, strontium, iron(II) and silver(I) ions.

Which carbonate will be precipitated first when 1 mol dm^{-3} sodium carbonate is added dropwise into the solution?

	compound	K_{sp}
A	Magnesium carbonate	1.3×10^{-7} mol^2 dm^{-6}
B	Strontium carbonate	9.3×10^{-10} mol^2 dm^{-6}
C	Iron(II) carbonate	2.1×10^{-11} mol^2 dm^{-6}
D	Silver(I) carbonate	8.1×10^{-12} mol^3 dm^{-9}

16 Ethyl ethanoate undergoes an acid-catalysed hydrolysis in water where the concentration of acid in the solution remains constant.

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

The rate equation is found to be rate = $k[CH_3CO_2CH_2CH_3][H^+]$

In an experiment, when 0.01 mol dm^{-3} HC*l* was reacted with 0.10 mol dm^{-3} ethyl ethanoate, the half-life was found to be 42 min.

In a second experiment, 0.02 mol dm^{-3} HC*l* was reacted with 0.40 mol dm^{-3} ethyl ethanoate.

What is the half-life of the second experiment?

A 6.25 min **B** 10.5 min **C** 21 min **D** 42 min

17 What is the rate equation for the reaction with the mechanism shown?

$$\begin{aligned} 2A &\rightleftharpoons A_2 &&\text{fast} \\ A_2 + B &\longrightarrow A_2B &&\text{slow} \\ A_2B + B &\longrightarrow A_2B_2 &&\text{fast} \end{aligned}$$

A Rate = $k[A]^2$

B Rate = $k[A][B]$

C Rate = $k[A_2][B]$

D Rate = $k[A]^2[B]$

18 Which species is the weakest oxidising agent under standard conditions?

A Ag^+ (aq) **B** Cu^{2+} (aq) **C** Fe^{2+} (aq) **D** H^+ (aq)

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19 Each gold medal awarded in the Olympic Games weighs 500 g. The gold plating constitutes 1.2% by mass of the gold medal.

The core of the medal is immersed in a solution of gold(III) chloride and connected to a power source with a current of 0.10 A.

What is the time required to electroplate the desired mass of gold?

A 1.76×10^4 s **B** 2.94×10^4 s **C** 8.81×10^4 s **D** 7.35×10^6 s

20 It has been estimated that for every atom of chlorine or bromine generated from a halogenoalkane in the stratosphere, one hundred thousand molecules of ozone may be destroyed.

Which organic compound would cause the most destruction to ozone?

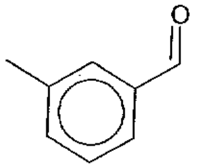
A $CF_2ClCH_2CF_2Cl$

B CCl_2BrCH_2Br

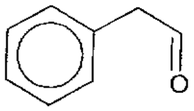
C $CHCl_2CBr_3$

D CCl_4

21 Compounds **X** and **Y** are isomers with the molecular formula C_8H_8O.



Compound **X**



Compound **Y**

Which reagent can be used to distinguish between **X** and **Y**?

A Hot acidified $K_2Cr_2O_7$

B Hot acidified $KMnO_4$

C $[Ag(NH_3)_2]^+$, heat

D I_2, NaOH(aq), warm

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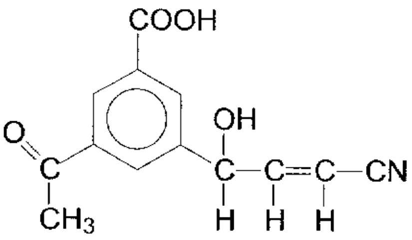
22 How many moles of H_2 will react with 1 mole of the following compound in the presence of platinum catalyst?



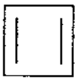
A 2 **B** 3 **C** 4 **D** 5

23 In 1931, the German chemist Erich Hückel formulated a theory to help determine if a species would be considered aromatic. This rule became known as Hückel's rule.

The compound must meet all the following four criteria to be considered as aromatic:

- a cyclic structure (a ring of atoms)
- a planar ring structure (all atoms in the ring must lie in the same plane)
- a fully conjugated ring structure (continuous lateral overlap of p orbitals at every atom in the ring)
- a ring structure has (4n+2) π electrons (n = 0 or any positive integer)

Which molecules are aromatic?

1


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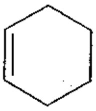

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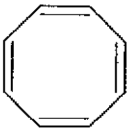

A 1 only

B 2 and 3 only

C 1 and 3 only

D None of the above

24 Which molecule **cannot** be used to synthesise propanoic acid in less than 3 steps?

A $CH_3CH_2COCH_3$

B $CH_3CH_2CONH_2$

C $CH_3CH_2CH_2CH_2Br$

D $CH_3CH_2OCOCH_3$

25 During the preparation of many organic compounds, by-products are formed. This usually occurs because the reagents can react in more than one way depending on the conditions used or because the products formed may react with the reactants.

Propanol is produced by the reaction between bromopropane and aqueous sodium hydroxide.

$$CH_3CH_2CH_2Br + NaOH \rightarrow CH_3CH_2CH_2OH + NaBr$$

What could be a by-product of this reaction?

1 $CH_3CH{=}CH_2$

2 $CH_3CH(OH)CH_3$

3 $CH_3CH_2CH_2ONa$

A 1, 2 and 3

B 1 and 3 only

C 1 only

D None of the above

26 The hydride ion, H^-, is a strong reducing agent, a good nucleophile and a good base.

Which conversion **cannot** be carried out by the hydride ion?

A C_3H_7Br to C_3H_8

B $CH_2{=}CH_2$ to CH_3CH_3

C C_6H_5OH to $C_6H_5O^-$

D CH_3CN to $CH_3CH_2NH_2$

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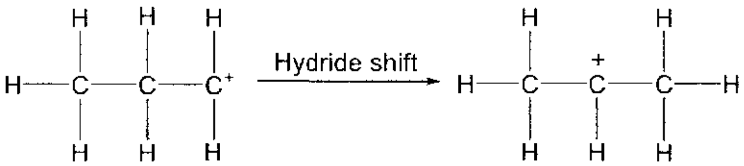
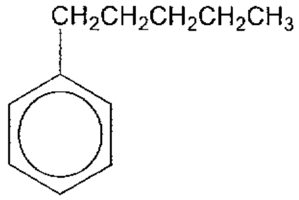
27 Hydride shift is a rearrangement process which produces a more stable carbocation. For example, after removing the halogen from $CH_3CH_2CH_2Cl$, a hydride shift will take place as shown.



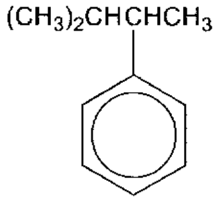
In another experiment, $(CH_3)_2CHCHClCH_3$ reacts with benzene in the presence of $FeCl_3$.

Which product would most likely be formed?

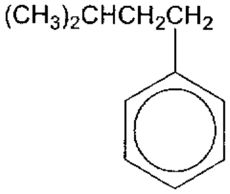
A



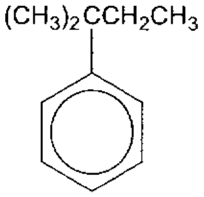
B



C



D



28 Which reaction yields a carbon compound incorporating deuterium, D? [D = $^{2}_{1}H$]

A $CH_3CHO \xrightarrow[\text{dry ether}]{LiAlD_4}$

B $CH_3CH_2CN \xrightarrow[D_2O]{NaOD}$

C $(CH_3)_3COH \xrightarrow[\text{heat}]{\text{conc. } D_2SO_4}$

D $CH_3CD(OD)CH_3 \xrightarrow[\text{heat}]{\text{acidified } KMnO_4}$

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29 What is the predominant form of glycine, NH_2CH_2COOH, in a solution of pH 3? (Given pK_{a1} = 2.3 and pK_{a2} = 9.6).

A $^+NH_3CH_2CO_2H$

B $^+NH_3CH_2CO_2^-$

C $NH_2CH_2CO_2H$

D $NH_2CH_2CO_2^-$

30 Transition metals like platinum and rhodium are found in catalytic converters fitted into cars. Which statement best explains the role of transition metals in this use?

A Transition metals can exhibit variable oxidation states in their compounds as 3d and 4s electrons have similar energies.

B Transition metals have available and partially filled 3d orbitals for the adsorption of reactant molecules.

C Transition metals have very high melting points because both 3d and 4s electrons are involved in forming strong metallic bonds.

D Transition metals form coloured ions due to absorption of energy in the visible light region to promote an electron from a lower to a higher energy 3d orbitals.

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Answer keys for 2021 SH2 H2 Chemistry Prelim Paper 1

1	C
2	A
3	C
4	C
5	A

11	A
12	A
13	A
14	A
15	C

21	B
22	C
23	D
24	D
25	C

6	D
7	C
8	D
9	C
10	C

16	C
17	D
18	C
19	C
20	C

26	B
27	D
28	A
29	B
30	B

1 A sample of element sulfur contains four isotopes of the following composition.

relative isotopic mass	relative abundance
32	95.02
33	0.76
34	4.20
36	0.02

What is the relative atomic mass of sulfur in this sample?

A 32.07 **B** 32.08 **C** 32.09 **D** 32.10

Ans : C

$$A_r = \left(\frac{95.02}{100} \times 32\right) + \left(\frac{0.76}{100} \times 33\right) + \left(\frac{4.2}{100} \times 34\right) + \left(\frac{0.02}{100} \times 36\right)$$
$$= 32.0924 \approx 32.09$$

2 When 15 cm^3 of a gaseous organic compound were completely burnt in an excess of oxygen, 30 cm^3 of carbon dioxide and 15 cm^3 of nitrogen were formed, all volumes being measured at the same temperature and pressure.

Which could be the formula of the organic compound?

A $C_2H_4N_2$ **B** C_2H_7NO **C** C_3H_7NO **D** $C_3H_6N_2$

Ans : A

According to the question, all the carbon atoms in the organic compound are converted into CO_2 when burnt completely in excess O_2, and the nitrogen atoms are converted into N_2.

Assuming that the formula of the organic compound is $C_xH_yN_z$, when one mole of $C_xH_yN_z$ undergoes combustion, x moles of CO_2 will be produced and z/2 moles of N_2 will be produced.

The volume ratio of organic compound : CO_2 : N_2 = 15 cm^3 : 30 cm^3 : 15 cm^3
Mol ratio = 1 : 2 : 1

Hence x = 2 and z = 2 which fits the molecular formula $C_2H_4N_2$.

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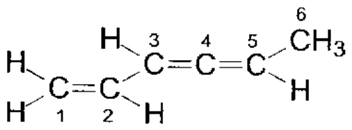
3 Which ion has less electrons than neutrons and less neutrons than protons?

	ion	neutrons	nucleons
A	A^-	18	37
B	B^{2+}	17	34
C	C^{3+}	16	33
D	D^{3-}	16	31

Ans : C

	Identity	**Neutrons**	**Protons**	**Electrons**
A	A^-	18	37 - 18 = 19	19 + 1 = 20
B	B^{2+}	17	34 - 17 = 17	17 – 2 = 15
C	C^{3+}	16	33 - 16 = 17	17 – 3 = 14
D	D^{3-}	16	31 – 16 = 15	15 + 3 = 18

4 Covalent bonds are formed by orbitals overlap.



Which statement does **not** describe the molecule above?

A The σ bond between C1–C2 is formed by $2sp^2$–$2sp^2$ overlap.

B The σ bond between C2–C3 is stronger than that between C5–C6.

C The π bond between C4–C5 is formed by $2sp$–$2sp^2$ overlap.

D The σ bond between C6–H is formed by $2sp^3$–$1s$ overlap.

Ans : C

Option A is correct. The σ bond between C1–C2 is formed by $2sp^2$–$2sp^2$ overlap.

Option B is correct. The σ bond between C2–C3 is formed by $2sp^2$–$2sp^2$ overlap while that between C5–C6 is formed by $2sp^2$–$2sp^3$ overlap. $2sp^2$–$2sp^2$ overlap is more effective due to the hybridised orbitals having greater s character and results in a stronger bond.

Option C is wrong. The π bonds between C3–C4 and C4–C5 should be formed by side–on overlap of unhybridised 2p orbitals, **NOT** the hybridised orbitals.

Option D is correct. The σ bond between C6–H is formed by head on overlap of $2sp^3$ of C and 1s of H.

5 Which options contain a polar and a non-polar molecule?

1 CO_2, H_2O

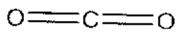
2 SO_2, PCl_5

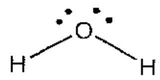
3 CH_2Cl_2 , $SiCl_4$

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

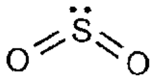
Ans : A

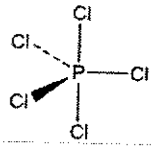
Option 1: CO_2 is non-polar while H_2O is polar



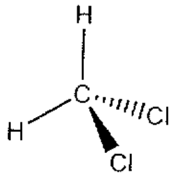


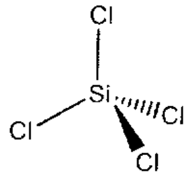
Option 2: SO_2 is polar while PCl_5 is non-polar



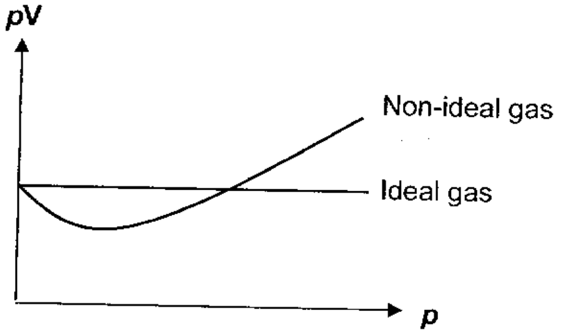


Option 3: CH_2Cl_2 is polar while $SiCl_4$ is non-polar





6 The value of pV is plotted against p for two gases, an ideal gas and a non-ideal gas, where p is the pressure and V is the volume of the gas.



Which gas shows the greatest deviation from ideal gas behaviour at 200 °C?

A CO_2 **B** Cl_2 **C** CH_3OH **D** N_2H_4

Ans : D

Deviation from ideal gas behaviour is greatest for molecules with strongest intermolecular forces of attraction.

Both CO_2 and Cl_2 are non-polar molecules with weaker instantaneous dipole-induced dipole interactions (id-id) as compared to CH_3OH and N_2H_4, which have stronger intermolecular hydrogen bonding. N_2H_4 has more extensive hydrogen bonds (an average of 2 H-bonds per molecule) than CH_3OH (an average of 1 H-bond per molecule), hence N_2H_4 exhibit greatest deviation from ideal gas behaviour.

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7 Astatine is an element in Group 17. Which statements are correct?

1 Silver astatide is insoluble in aqueous ammonia.

2 Hydrogen astatide is less stable to heat than hydrogen iodide.

3 Astatine is more electronegative than iodine.

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

Ans : C

Astatine is below iodine in Group 17.

Option 1 is correct, solubility of AgX ppt in NH_3 decreases down the group.

Option 2 is correct, thermal stability decreases down the group due to weaker H–X bond.

Option 3 is wrong, Electronegativity decreases down the group.

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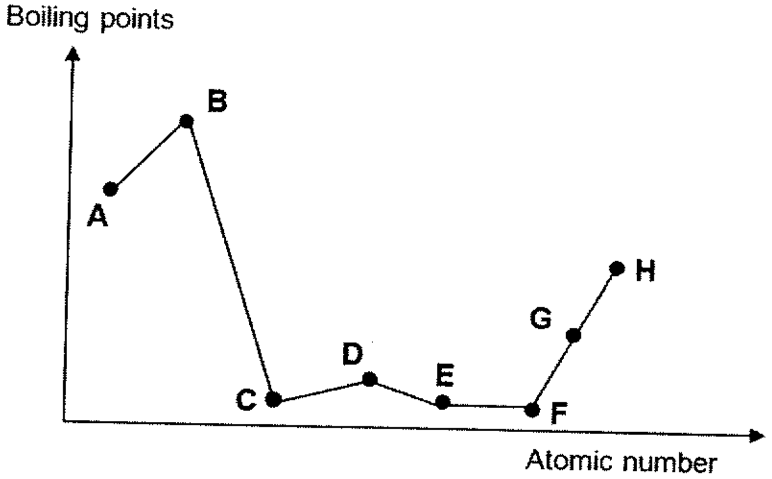
8 The graph below shows the variation in the boiling point for 8 consecutive elements in the Periodic Table, all with atomic number ≤ 20.



What can be deduced from the graph?

A The ions of **A** and **E** are isoelectronic.

B The chlorides become less acidic from **A** to **C**.

C When the oxide of **D** is added to water, the resulting solution has a pH greater than 7

D The oxide of **A** reacts with excess aqueous sodium hydroxide to form a soluble complex.

Ans : D

Drastic drop in boiling point from B to C => change in structure from giant covalent to simple covalent. B is Silicon, C is Phosphorus.

Option A is wrong. A is Aluminium (Group 13). Ions of A (Al^{3+}) and E(Cl^-) are not isoelectronic (Cl^- have 8 more electrons than Al^{3+})

Option B is wrong. Chloride of A ($AlCl_3$) is acidic (pH = 3) due to significant hydrolysis to give H^+ ions, chlorides of B ($SiCl_4$) and C (PCl_5) are more acidic as they produce strong acid HCl in water.

Option C is wrong. Oxide of D is SO_3. $SO_3 + H_2O \longrightarrow H_2SO_4$ which is acidic (pH < 7).

Option D is correct. Oxide of A (Al_2O_3) is amphoteric and can react with both acids & bases. It reacts with excess aq NaOH to form soluble complex $Na[Al(OH)_4]$.

9 Given the following data:

Lattice energy of magnesium chloride	–2526 kJ mol^{-1}
Standard enthalpy change of hydration of chloride	–384 kJ mol^{-1}
Standard enthalpy change of hydration of magnesium	–1890 kJ mol^{-1}

What would be the change in temperature measured when 0.49 g of magnesium chloride was dissolved in 50 g of water?
[Molar mass of $MgCl_2$ = 95.3 g mol^{-1}]

A - 6.2 °C **B** - 3.3 °C **C** + 3.3 °C **D** + 6.2 °C

Ans : C

$\Delta H_{sol} = \Delta H_{hyd}(Mg^{2+}) + 2\Delta H_{hyd}(Cl^{-}) - LE(MgCl_2)$ +
$= (-1890) + 2(-384) - (-2526)$
$= -132$ kJ mol^{-1}

Amt of $MgCl_2$ in 0.49 g = 0.49/95.3 = 5.142×10^{-3} mol
Heat gained by water, q = heat evolved = $132 \times 5.142 \times 10^{-3}$ = 0.6787 kJ = 678.7 J

$q = mc\Delta T$
$\Delta T = \frac{q}{mc} = \frac{(678.7)}{(50 \times 4.18)}$ = +3.25 °C (exothermic reaction, ΔT is positive)

10 Combustion of carbon monoxide to form carbon dioxide is an exothermic reaction.

What can be deduced from this information?

1 CO_2 is more stable than CO.

2 The standard enthalpy change of formation of carbon dioxide is more exothermic than the standard enthalpy change of formation of carbon monoxide.

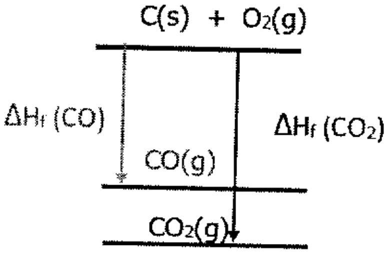
3 Combustion of CO has a low activation energy.

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

Ans : C

Option 1 is correct, since combustion is an exothermic process, energy level of CO_2 is lower than that of CO, hence CO_2 is more stable than CO.

Option 2 is correct, formation of $CO_2(g)$ from $C(s) + O_2(g)$ is an exothermic reaction (combustion). Since CO_2 has a lower energy level than CO, ΔH_f $CO_2(g)$ will be more exothermic than ΔH_f CO(g).



Option 3 cannot be deduced as ΔH_c does not predict rate of reaction.

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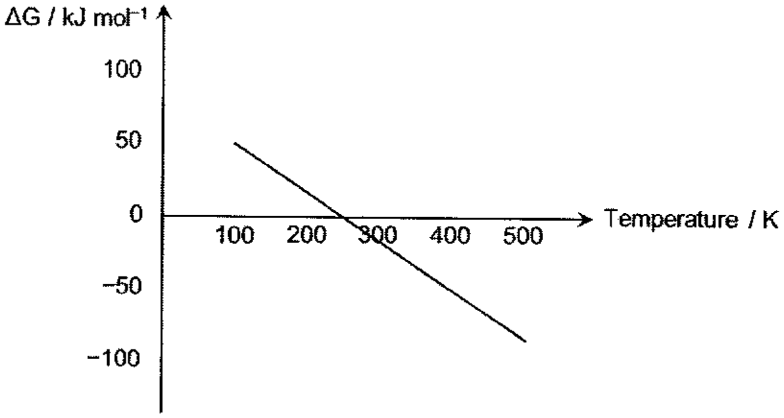
11 What can be concluded about the values of ΔH and ΔS from this graph?



	ΔH	ΔS
A	positive	positive
B	positive	negative
C	negative	positive
D	negative	negative

Ans : A

$\Delta G = \Delta H - T\Delta S$
$Y = mX + c$
y-intercept (c) is ΔH, gradient (m) is −ΔS
From the graph when T = 0 K, ΔG is positive. This indicates that ΔH is positive as $T\Delta S = 0$.
Gradient is a negative value, hence ΔS is position.
OR
ΔG becomes more negative as temperature increases indicates that ΔS is a positive value as with a larger T, TΔS became more larger resulting in ΔG to become more negative.

[Turn over

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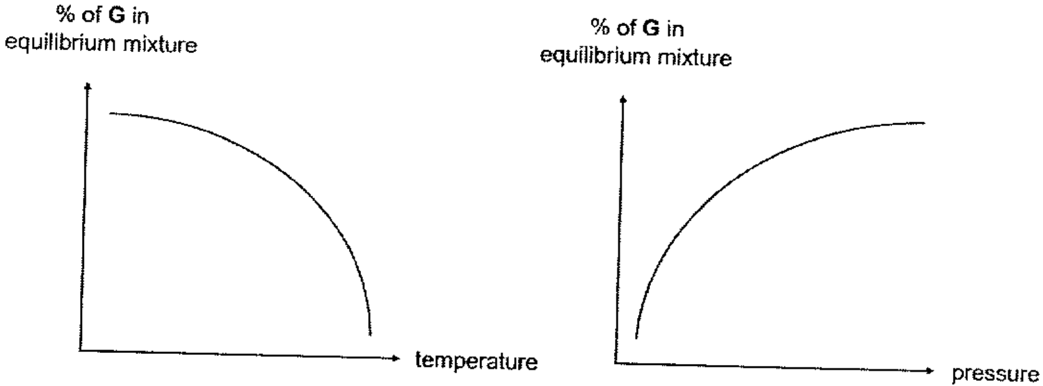
12 Compound **G** is formed during a reaction involving only gaseous particles.
The graphs below show how the percentage of compound **G** at equilibrium varies with temperature and pressure.



Which equation represents the formation of compound **G**?

	equation	ΔH
A	$E(g) + 3F(g) \rightleftharpoons 2G(g)$	negative
B	$2E(g) \rightleftharpoons F(g) + 2G(g)$	positive
C	$4D(g) + 3E(g) \rightleftharpoons 2F(g) + 6G(g)$	negative
D	$E(g) + F(g) \rightleftharpoons 2G(g)$	positive

Ans : A

From the graphs, % of product **G** decreases with increasing temperature and % of product **G** increases with increasing pressure.
The increase in temperature causes position of equilibrium to shift left, favouring the endothermic reaction, hence forward reaction is exothermic.
The increase in pressure causes position of equilibrium to shift right, favouring the production of lesser moles of gas, hence forward reaction produces lesser mol of gas.

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13 Which reactions show NH_3 behaving as a Lewis base?

1 $HNO_3 + NH_3 \longrightarrow NH_4NO_3$

2 $2NH_3 \longrightarrow NH_2^- + NH_4^+$

3 $BH_3 + NH_3 \longrightarrow BH_3NH_3$

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

Ans : A

Lewis base is an electron pair donor.

Option 1 is correct, NH_3 donates electron pair to accept H^+ from HNO_3.

Option 2 is correct, NH_3 donates electron pair to accept H^+ from the other NH_3.

Option 3 is correct, NH_3 donates electron pair to BH_3 via dative bond.

14 The auto-ionisation of H_2O is an endothermic process.

$$H_2O(l) \rightleftharpoons H^+(aq) + OH^-(aq) \qquad K_w = 1.0 \times 10^{-14} \text{ at } 25\ ^\circ C$$

Which option is correct about water at 60 °C?

A pH < 7 **B** pH = 7 **C** $[H^+] > [OH^-]$ **D** $[H^+] < [OH^-]$

Ans : A

The auto-ionisation of water is endothermic, at a higher temperature of 60 °C, the position of equilibrium favours the forward direction, hence $K_w > 1.0 \times 10^{-14}$.
Since $pK_w = pH + pOH$ and pH = pOH for neutrality, a larger K_w leads to a smaller pK_w which will result in pH and pOH BOTH taking a value below 7.

Options **C** and **D** are common misconceptions. The position of equilibrium is different at a different temperature, but the new $[H^+]$ and the new $[OH^-]$ remain equal.

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15 A 1 dm^3 solution contains 2×10^{-4} mol dm^{-3} each of magnesium, strontium, iron(II) and silver(I) ions.

Which carbonate will be precipitated first when 1 mol dm^{-3} sodium carbonate is added dropwise into the solution?

	compound	K_{sp}
A	Magnesium carbonate	1.3×10^{-7} $mol^2\ dm^{-6}$
B	Strontium carbonate	9.3×10^{-10} $mol^2\ dm^{-6}$
C	Iron(II) carbonate	2.1×10^{-11} $mol^2\ dm^{-6}$
D	Silver(I) carbonate	8.1×10^{-12} $mol^3\ dm^{-9}$

Ans : C

$K_{sp}(MgCO_3) = [Mg^{2+}][CO_3^{2-}]$
$1.3 \times 10^{-7} = (2 \times 10^{-4})[CO_3^{2-}]$
$[CO_3^{2-}] = \frac{1.3 \times 10^{-7}}{2 \times 10^{-4}} = 6.5 \times 10^{-4}$ mol dm^{-3}

$K_{sp}(SrCO_3) = [Sr^{2+}][CO_3^{2-}]$
$9.3 \times 10^{-10} = (2 \times 10^{-4})[CO_3^{2-}]$
$[CO_3^{2-}] = \frac{9.3 \times 10^{-10}}{2 \times 10^{-4}} = 4.65 \times 10^{-6}$ mol dm^{-3}

$K_{sp}(FeCO_3) = [Fe^{2+}][CO_3^{2-}]$
$2.1 \times 10^{-11} = (2 \times 10^{-4})[CO_3^{2-}]$
$[CO_3^{2-}] = \frac{2.1 \times 10^{-11}}{2 \times 10^{-4}} = 1.05 \times 10^{-7}$ mol dm^{-3} (lowest conc of CO_3^{2-} required, ppt first)

$K_{sp}(Ag_2(CO_3)) = [Ag^+]^2[CO_3^{2-}]$
$8.1 \times 10^{-12} = (2 \times 10^{-4})^2[CO_3^{2-}]$
$[CO_3^{2-}] = \frac{8.1 \times 10^{-12}}{(2 \times 10^{-4})^2} = 2.03 \times 10^{-4}$ mol dm^{-3}

16 Ethyl ethanoate undergoes an acid-catalysed hydrolysis in water where the concentration of acid in the solution remains constant.

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

The rate equation is found to be rate = $k[CH_3CO_2CH_2CH_3][H^+]$

In an experiment, when 0.01 mol dm^{-3} HC*l* was reacted with 0.10 mol dm^{-3} ethyl ethanoate, the half-life was found to be 42 min.

In a second experiment, 0.02 mol dm^{-3} HC*l* was reacted with 0.40 mol dm^{-3} ethyl ethanoate.

What is the half-life of the second experiment?

A 6.25 min **B** 10.5 min **C** 21 min **D** 42 min

Ans : C

Since HC*l* is the catalyst and is regenerated at the end of the reaction, concentration of HC*l* remains constant during the reaction, this is a pseudo-first order reaction.
rate = $k'[CH_3CO_2CH_2CH_3]$ where $k' = k[H^+]$

For 1st order reaction, half-life, $t_{1/2} = \frac{ln\,2}{k'}$
In this reaction, $t_{1/2} = \frac{ln\,2}{k\,[H^+]}$
when [HC*l*] = 0.01 mol dm^{-3}, half-life = 42 min,
when [HC*l*] = 0.02 mol dm^{-3}, half-life = 21 min.

17 What is the rate equation for the reaction with the mechanism shown?

$$\begin{array}{rcll} 2A & \rightleftharpoons & A_2 & \text{fast} \\ A_2 + B & \longrightarrow & A_2B & \text{slow} \\ A_2B + B & \longrightarrow & A_2B_2 & \text{fast} \end{array}$$

A Rate = $k[A]^2$

B Rate = $k[A][B]$

C Rate = $k[A_2][B]$

D Rate = $k[A]^2[B]$

Ans : D

fast equilibrium step 1 $K_c = \frac{[A_2]}{[A]^2}$
$[A_2] = K_c\,[A]^2$

From slow step, rate $= k\,[A_2]\,[B]$
$= k\,(K_c\,[A]^2)\,[B]$
$= k'\,[A]^2[B]$

Note : intermediate cannot appear in the rate equation.

18 Which species is the weakest oxidising agent under standard conditions?

A Ag^+ (aq) **B** Cu^{2+} (aq) **C** Fe^{2+} (aq) **D** H^+ (aq)
Ans : C

Weakest oxidising agent is one that is least likely to be reduced. It would have the least positive $E^\ominus$ value.

$Ag^+ + e^- \rightleftharpoons Ag$ +0.80
$Cu^{2+} + e^- \rightleftharpoons Cu^+$ +0.15
$Cu^{2+} + 2e^- \rightleftharpoons Cu$ +0.34
$Fe^{2+} + 2e^- \rightleftharpoons Fe$ −0.44
$2H^+ + 2e^- \rightleftharpoons H_2$ 0.00

19 Each gold medal awarded in the Olympic Games weighs 500 g. The gold plating constitutes 1.2% by mass of the gold medal.

The core of the medal is immersed in a solution of gold(III) chloride and connected to a power source with a current of 0.10 A.

What is the time required to electroplate the desired mass of gold?

A 1.76×10^4 s **B** 2.94×10^4 s **C** 8.81×10^4 s **D** 7.35×10^6 s
Ans : C

[R] $Au^{3+} + 3e^- \longrightarrow Au$
Amt of Au = $\frac{6.0}{197.0}$ = 0.03046 mol
Amt of e^- = 3 × 0.03046 = 0.09137 mol
$Q = I \times t = n_e \times F$
$(0.10) \times t = 0.09137 \times 96500$
t = 88173 s

20 It has been estimated that for every atom of chlorine or bromine generated from a halogenoalkane in the stratosphere, one hundred thousand molecules of ozone may be destroyed.

Which organic compound would cause the most destruction to ozone?

A $CF_2ClCH_2CF_2Cl$

B CCl_2BrCH_2Br

C $CHCl_2CBr_3$

D CCl_4
Ans : C

Option C contains the greatest number of chlorine and bromine atom.

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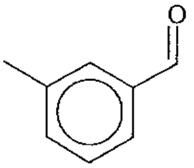
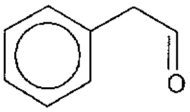
21 Compounds **X** and **Y** are isomers with the molecular formula C_8H_8O.



Compound **X**



Compound **Y**

Which reagent can be used to distinguish between **X** and **Y**?

A Hot acidified $K_2Cr_2O_7$

B Hot acidified $KMnO_4$

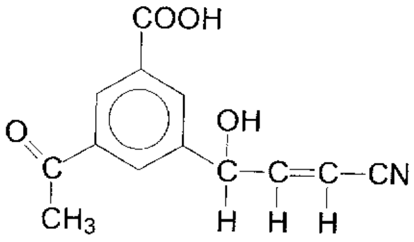
C $[Ag(NH_3)_2]^+$, heat

D I_2, NaOH(aq), warm

Ans : B

	Compound **X**	Compound **Y**
Hot acidified $K_2Cr_2O_7$ (oxidation of all aldehyde)	Orange $K_2Cr_2O_7$ turns green	Orange $K_2Cr_2O_7$ turns green
Hot acidified $KMnO_4$ (oxidation of alkyl side chain of benzene and aldehyde)	Purple $KMnO_4$ decolourises. No effervescence.	Purple $KMnO_4$ decolourises with effervescence of CO_2 that gives white ppt with $Ca(OH)_2$
$[Ag(NH_3)_2]^+$, heat (Tollens' reagent, oxidation of all aldehyde)	Silver mirror formed	Silver mirror formed
I_2, NaOH(aq), warm	No yellow ppt	No yellow ppt

22 How many moles of H_2 will react with 1 mole of the following compound in the presence of platinum catalyst?



A 2 **B** 3 **C** 4 **D** 5

Ans : C

1 mol of H_2 to react with ketone
1 mol of H_2 to react with C=C
2 mol of H_2 to react with C≡N
$H_2(g)$ with Pt is not able to reduce benzene and –COOH

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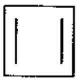
23 In 1931, the German chemist Erich Hückel formulated a theory to help determine if a species would be considered aromatic. This rule became known as Hückel's rule.

The compound must meet all the following four criteria to be considered as aromatic:

- a cyclic structure (a ring of atoms)
- a planar ring structure (all atoms in the ring must lie in the same plane)
- a fully conjugated ring structure (continuous lateral overlap of p orbitals at every atom in the ring)
- a ring structure has (4n+2) π electrons (n = 0 or any positive integer)

Which molecules are aromatic?

1


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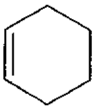
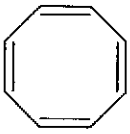


3


A 1 only

B 2 and 3 only

C 1 and 3 only

D None of the above

Ans : D

Option 1 is not aromatic. Each of the four atoms in the ring contain an unhybridised p orbital (C=C). It has total of 4π electrons (4π electrons from 2 C=C pi bonds), not 4n+2.

Option 2 is not aromatic. The four sp^3 hybridised C atoms is tetrahedral in geometry, hence it does not have a planar ring structure.

Option 3 is not aromatic. Each of the eight atoms in the ring contain an unhybridised p orbital (C=C). It has total of 8π electrons (8π electrons from 4 C=C pi bonds), not 4n+2.

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24 Which molecule **cannot** be used to synthesise propanoic acid in less than 3 steps?

A $CH_3CH_2COCH_3$

B $CH_3CH_2CONH_2$

C $CH_3CH_2CH_2CH_2Br$

D $CH_3CH_2OCOCH_3$

Ans : D

Option A step 1 $CH_3CH_2COCH_3 \xrightarrow{I_2\ /\ NaOH,\ warm} CH_3CH_2COO^-$ step 2 $CH_3CH_2COO^- \xrightarrow{HCl\ (aq)} CH_3CH_2COOH$	Option B $CH_3CH_2CONH_2 \xrightarrow[\text{heat under reflux}]{HCl(aq)} CH_3CH_2COOH$
Option C step 1 $CH_3CH_2CH_2CH_2Br \xrightarrow[\text{heat under reflux}]{\text{ethanolic NaOH}} CH_3CH_2CH{=}CH_2$ step 2 $CH_3CH_2CH{=}CH_2 \xrightarrow[\text{heat under reflux}]{KMnO_4\text{ in }H_2SO_4(aq)} CH_3CH_2COOH$	Option D step 1 $CH_3CH_2{-}O{-}\overset{\overset{O}{\parallel}}{C}{-}CH_3 \xrightarrow[\text{heat under reflux}]{HCl\ (aq)} CH_3CH_2OH$ step 2 $CH_3CH_2OH \xrightarrow{PCl_5} CH_3CH_2Cl$ step 3 $CH_3CH_2Cl \xrightarrow[\text{heat under reflux}]{\text{ethanolic NaCN}} CH_3CH_2CN$ step 4 $CH_3CH_2CN \xrightarrow[\text{heat under reflux}]{HCl\ (aq)} CH_3CH_2COOH$

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25 During the preparation of many organic compounds, by-products are formed. This usually occurs because the reagents can react in more than one way depending on the conditions used or because the products formed may react with the reactants.

Propanol is produced by the reaction between bromopropane and aqueous sodium hydroxide.

$$CH_3CH_2CH_2Br + NaOH \rightarrow CH_3CH_2CH_2OH + NaBr$$

What could be a by-product of this reaction?

1 $CH_3CH{=}CH_2$

2 $CH_3CH(OH)CH_3$

3 $CH_3CH_2CH_2ONa$

A 1, 2 and 3

B 1 and 3 only

C 1 only

D None of the above
Ans : C

Option 1 is correct. The product $CH_3CH_2CH_2OH$ provides an alcoholic medium for elimination of H and Br from $CH_3CH_2CH_2Br$ to occur:
$CH_3CH_2CH_2Br + NaOH(alc) \longrightarrow CH_3CH{=}CH_2 + NaBr + H_2O$

Option 2 is wrong. $CH_3CH(OH)CH_3$ would require reaction of $CH_3CH{=}CH_2$ with H_2O in presence of concentrated acid.

Option 3 is wrong. $CH_3CH_2CH_2OH$ is neutral and would not react with NaOH

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26 The hydride ion, H^-, is a strong reducing agent, a good nucleophile and a good base.

Which conversion **cannot** be carried out by the hydride ion?

A C_3H_7Br to C_3H_8

B $CH_2{=}CH_2$ to CH_3CH_3

C C_6H_5OH to $C_6H_5O^-$

D CH_3CN to $CH_3CH_2NH_2$

Ans : B

Option A: C_3H_7Br to C_3H_8. H^-, being a good nucleophile, undergoes nucleophilic substitution with C_3H_7Br to form C_3H_8.

Option B: $CH_2{=}CH_2$ to CH_3CH_3. H^-, being negatively charged, **does not react** with electron rich C=C bond in $CH_2{=}CH_2$.

Option C: C_6H_5OH to $C_6H_5O^-$. H^-, being a good base, undergoes acid base reaction with acidic phenol, C_6H_5OH to form $C_6H_5O^-$ + H_2.

Option D: CH_3CN to $CH_3CH_2NH_2$. H^-, being a strong reducing agent, reacts with the d+ C in C≡N of CH_3CN and reduces it to form $CH_3CH_2NH_2$.

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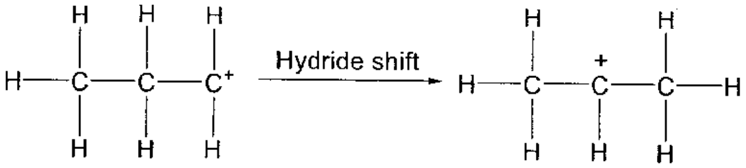
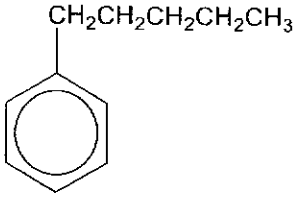
27 Hydride shift is a rearrangement process which produces a more stable carbocation. For example, after removing the halogen from $CH_3CH_2CH_2Cl$, a hydride shift will take place as shown.



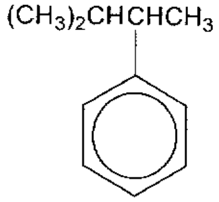
In another experiment, $(CH_3)_2CHCHClCH_3$ reacts with benzene in the presence of $FeCl_3$.

Which product would most likely be formed?

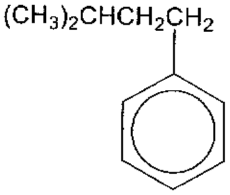
A



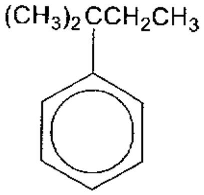
B



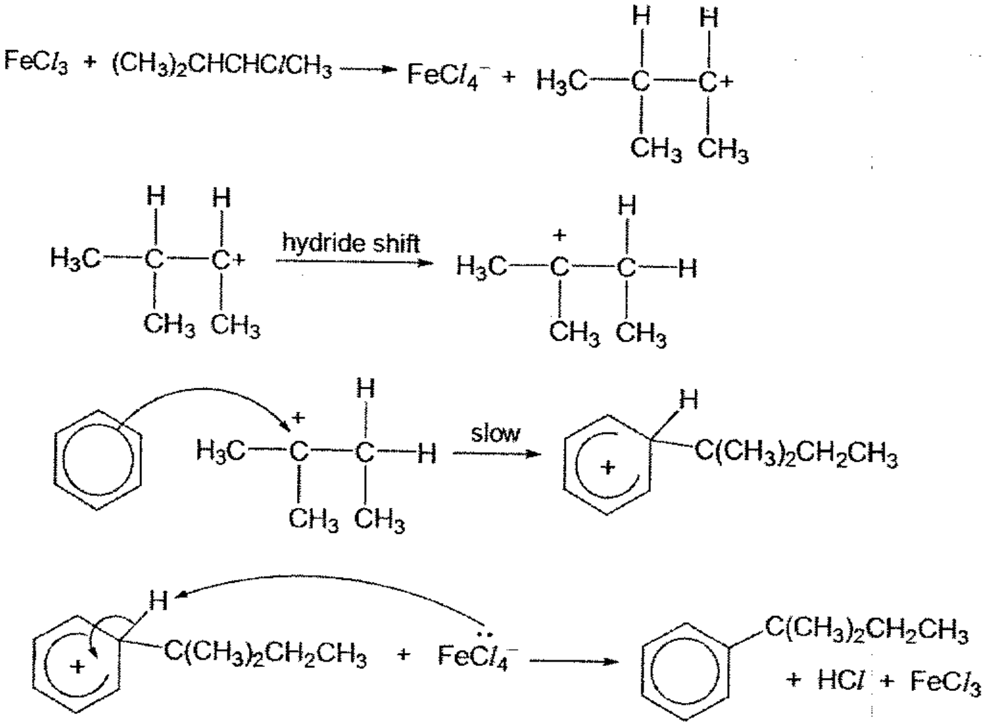
C



D



Ans : D



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28 Which reaction yields a carbon compound incorporating deuterium, D? [D = $^{2}_{1}H$]

A $CH_3CHO \xrightarrow[\text{dry ether}]{LiA/D_4}$

B $CH_3CH_2CN \xrightarrow[D_2O]{NaOD}$

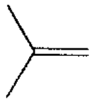
C $(CH_3)_3COH \xrightarrow[\text{heat}]{\text{conc. } D_2SO_4}$

D $CH_3CD(OD)CH_3 \xrightarrow[\text{heat}]{\text{acidified } KMnO_4}$

Ans : A

A) Reduction $CH_3CHO \xrightarrow[\text{dry ether}]{LiA/D_4}$ $\mathbf{CH_3CH(D)OH}$

B) Alkaline Hydrolysis $CH_3CH_2CN \xrightarrow[D_2O]{NaOD}$ $CH_3CH_2COO^{-}Na^{+}$

C) Elimination $(CH_3)_3COH \xrightarrow[\text{heat}]{\text{conc. } D_2SO_4}$  + H_2O

D) Oxidation $CH_3CD(OD)CH_3 \xrightarrow[\text{heat}]{\text{acidified } KMnO_4}$ CH_3COCH_3

29 What is the predominant form of glycine, NH_2CH_2COOH, in a solution of pH 3? (Given $pK_{a1} = 2.3$ and $pK_{a2} = 9.6$).

A $^{+}NH_3CH_2CO_2H$

B $^{+}NH_3CH_2CO_2^{-}$

C $NH_2CH_2CO_2H$

D $NH_2CH_2CO_2^{-}$

Ans: B

pK_a is for the $-COOH$ and $-NH_3^{+}$ groups in the protonated glycine.

$-COOH$ (lower pK_a, 2.3) is more acidic than $-NH_3^{+}$ (higher pK_a, 9.6).

When pH = pK_a, ratio of $-COOH$ (weak acid)= $-COO^{-}$(conjugate base) is 1:1.

Since solution of pH 3 is higher than the pK_a of the $-COOH$ (2.3), this indicates that predominant form is $-COO^{-}$.

Since solution of pH 3 is lower than the pK_a of $-NH_3^{+}$. The predominant form is $-NH_3^{+}$.

The main form of glycine in a solution of pH 3 is $^{+}NH_3CH_2CO_2^{-}$

30 Transition metals like platinum and rhodium are found in catalytic converters fitted into cars. Which statement best explains the role of transition metals in this use?

A Transition metals can exhibit variable oxidation states in their compounds as 3d and 4s electrons have similar energies.

B Transition metals have available and partially filled 3d orbitals for the adsorption of reactant molecules.

C Transition metals have very high melting points because both 3d and 4s electrons are involved in forming strong metallic bonds.

D Transition metals form coloured ions due to absorption of energy in the visible light region to promote an electron from a lower to a higher energy 3d orbitals.

Ans : B

Transition Element concepts

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NATIONAL JUNIOR COLLEGE
SH2 PRELIMINARY EXAMINATION
Higher 2

CANDIDATE NAME

SUBJECT CLASS

REGISTRATION NUMBER

CHEMISTRY

Paper 2 Structured Questions

9729/02
24 August 2021
2 hours

Candidates answer on Question Paper.
Additional Materials: Data Booklet

READ THE INSTRUCTIONS FIRST

Write your subject class, registration number and name on all the work you hand in.
Write in dark blue or black pen on both sides of the paper.
You may use a soft pencil for any diagrams, graphs or rough working.
Do not use paper clips, highlighters, glue or correction fluid.

Answers **all** questions.

The number of marks is given in brackets [ ] at the end of each question or part question.

For Examiner's Use	
1	/8
2	/12
3	/8
4	/11
5	/17
6	/19
Paper 2 Total	/75

	Marks	**Weightings**
Paper 1	/30	**15%**
Paper 2	/75	**30%**
Paper 3	/80	**35%**
Paper 4	/55	**20%**

Overall Percentage	
Grade	

This document consists of **23** printed pages and **1** blank page.

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Answer **all** the questions in the spaces provided.

1 **(a)** Iodine can undergo a reaction with aqueous potassium hydroxide to form iodate and iodide ions as shown in the following equation.

$$3I_2(s) + 6KOH(aq) \longrightarrow KIO_3(aq) + 5KI(aq) + 3H_2O(l)$$

This reaction has a potential application in times of nuclear catastrophe when radioactive and volatile iodine-131 is produced. Spraying alkalis into the nuclear reactors can convert the volatile iodine into non-volatile iodate and iodide ions, thus minimizing the damaging radioactive effects.

(i) Name the type of reaction for the above equation.

....

[1]

(ii) Write the two balanced half-equations for the above reaction.

....

....

[2]

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(b) The reaction of iodide and peroxodisulfate ions is very slow and can be catalysed by using a homogeneous catalyst.

$$S_2O_8^{2-} + 2I^- \longrightarrow 2SO_4^{2-} + I_2$$

(i) Explain why the rate of the above reaction is slow.

....

....

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[1]

(ii) With the aid of the Boltzmann distribution, explain how addition of a homogenous catalyst helps to increase the rate of a reaction.

....

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[2]

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(iii) By considering relevant $E^\ominus$ values from the *Data Booklet*, explain how Fe^{3+}(aq) can act as a homogenous catalyst in this reaction.

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[2]

[Total : 8]

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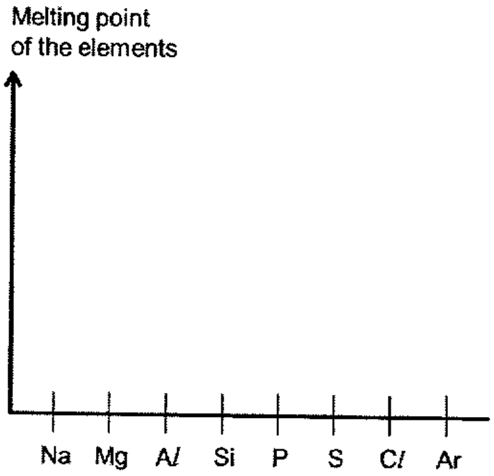
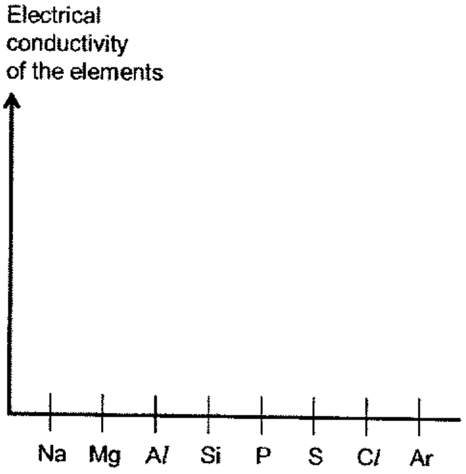
2 **(a)** The Period 3 elements vary in their physical properties.

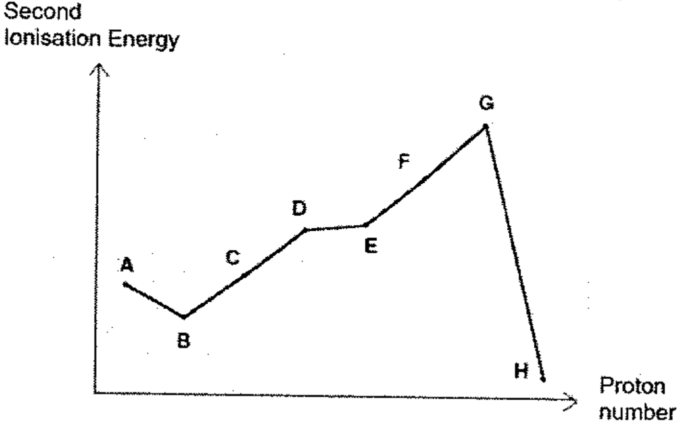
(i) On the axes below, sketch the melting point and electrical conductivity trends for the **stated elements**.





[2]

(ii) Sulfur is an element in Period 3 of the Periodic Table. The graph below shows the second ionisation energies of eight elements with consecutive proton number.



Which of the elements **A** to **H** represents sulfur? Explain your answer.

[2]

[Turn over

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(b) A 0.400 g solid sample of a mineral, $\mathbf{XY(CO_3)_2}$ (where **X** and **Y** are Group 2 elements) was heated strongly to give a mixture of oxides of **X** and **Y** and carbon dioxide. The solid mixture has a total mass of 0.275 g.

The solid mixture was added to excess water and stirred. The suspension was filtered, and the oxide of **X** was obtained as a residue. The dried residue weighed 0.057 g.

(i) Write a balanced equation for the decomposition of $\mathbf{XY(CO_3)_2}$

....

[1]

(ii) Calculate the mass of carbon dioxide produced.

[1]

(iii) Hence, or otherwise, identify the metals, **X** and **Y**, showing your working clearly.

[3]

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(c) Aluminium is commonly extracted from its oxide, Al_2O_3.

(i) Al_2O_3 dissolves in hot aqueous solution of sodium hydroxide.

Write an ionic equation to explain the reaction.

.... [1]

(ii) Al_2O_3 is dissolved in molten cryolite. The mixture is electrolysed using graphite electrodes. The cell operates at a very high current of 50 000 A.

Calculate the time needed to obtain 1 kg of pure aluminium.

[2]

[Total : 12]

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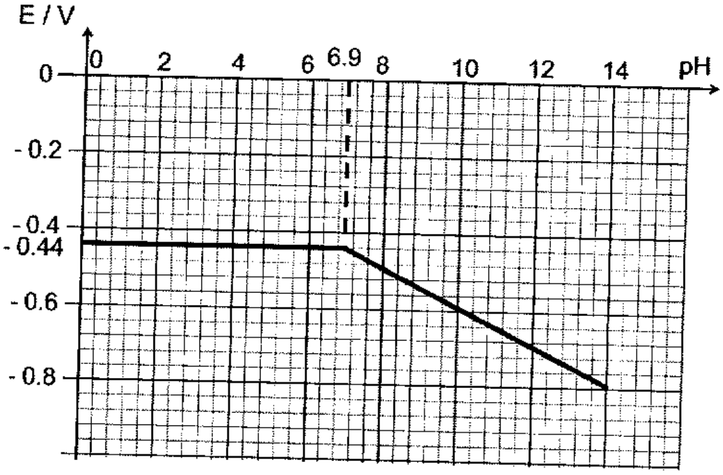
3 A student wanted to investigate the effect of pH on the electrode potential, *E*, of an iron(II)/ iron half-cell.

She started the experiment with 1 mol dm^{-3} Fe^{2+} with Fe electrode at pH 0. NaOH(aq) was added dropwise to the solution and the following data was collected.



(i) Using the information provided, show that the green $Fe(OH)_2$ precipitate is produced at approximately pH 6.9.
(Solubility product, K_{sp}, of $Fe(OH)_2$ = 6.0×10^{-15} mol^3 dm^{-9} at 25 °C)

[2]

(ii) With the use of the *Data Booklet*, explain the shape of the graph as fully as you can.

....

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[3]

(iii) Explain why $Fe(OH)_2$ is green.

....

....

....

....

....

....

[3]

[Total : 8]

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4 (a) Nitroglycerin, $C_3H_5(NO_3)_3$, is a flammable oil commonly used to manufacture dynamite. The atomisation of nitroglycerin is represented by the equation:

$$C_3H_5(NO_3)_3(l) \longrightarrow 3C(g) + 5H(g) + 3N(g) + 9O(g)$$

Table 4.1

Standard enthalpy change of formation of nitroglycerin(l) / kJ mol^{-1}	−364
Standard enthalpy change of atomisation of carbon (graphite) / kJ mol^{-1}	+715
Standard enthalpy change of formation of $H_2O(g)$ / kJ mol^{-1}	−242
Standard enthalpy change of formation of $CO_2(g)$ / kJ mol^{-1}	−394

(i) Using data from Table 4.1 and relevant values from the *Data Booklet*, draw an energy cycle and use it to calculate the standard enthalpy change of atomisation of nitroglycerin.

[3]

(ii) At high temperature, nitroglycerin decomposes to produce nitrogen, oxygen, carbon dioxide and steam.

Write a balanced equation, with state symbols, for the decomposition of nitroglycerin.

....

[1]

(iii) Using data from Table 4.1, calculate the standard enthalpy change of decomposition of nitroglycerin.

[1]

(iv) Given that $\Delta S^\ominus = +208\ \text{J K}^{-1}\text{mol}^{-1}$, calculate $\Delta G^\ominus$ for this decomposition and hence predict the spontaneity of the reaction.

[2]

(v) Is the reaction spontaneous at all temperatures? Explain.

....

....

....

....

[1]

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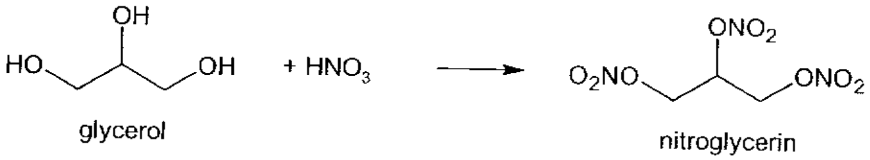
(b) Nitroglycerin can be produced by reaction of glycerol with nitric acid.



(i) Write a balanced equation for the reaction and hence identity the type of reaction.

Type of reaction : ....

[2]

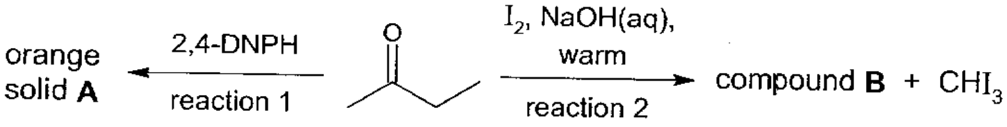
(ii) Give the IUPAC name for glycerol.

....

[1]

[Total : 11]

5 **(a)** Butanone, $CH_3COCH_2CH_3$, is a commonly used organic solvent.



(i) Butanone reacts with 2,4-dinitrophenylhydrazine to give an orange solid **A**. Suggest the type of reaction and draw the structure of **A**.

Type of reaction : ....

structure of **A**

[2]

(ii) Suggest the identity of compound **B**.

....

[1]

(iii) When CHI_3 is heated strongly with OH^-(aq), a mixture containing $HCOO^-$ and I^- is obtained.

Write a balanced equation for this reaction.

....

[1]

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(iv) **The use of the table of characteristic infra-red absorption frequencies for some selected bonds in the *Data Booklet* is relevant to this question.**

Tetrahydrofuran is a functional group isomer of butanone and has no reaction with anhydrous $SOCl_2$ nor Br_2(aq).

Infra-red absorptions can be used to identity functional groups in organic compounds. For example, butanone shows absorption at 1680 cm^{-1} due to the C=O bond.

The analysis of tetrahydrofuran shows infra-red absorption at 1000 cm^{-1}.

Identify the bond present in tetrahydrofuran and suggest its structure.

Bond present : ....

structure of tetrahydrofuran

[2]

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(b) Compound **C** has the molecular formula $C_7H_{14}O$. It contains two functional groups.

Data about the reactions of **C** are given in Table 5.1.

Table 5.1

reaction	reagent	result
b1	Na(s)	colourless gas evolved.
b2	I_2 in CCl_4	one organic product formed with M_r = 367.8
b3	$KMnO_4$, H_2SO_4(aq), heat	butanone and compound **D**, $C_3H_4O_3$, formed.

(i) Name the functional group that reaction **b1** shows to be present in **C**.

.... [1]

(ii) Write the balanced equation for reaction **b1**.

.... [1]

(iii) Deduce the molecular formula of the organic product formed in reaction **b2**.

.... [1]

(iv) Draw the structure of compound **D** produced from reaction **b3**.

[1]

(v) Draw the structure of **C** given that it is optically inactive.

[1]

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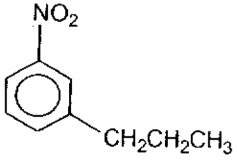
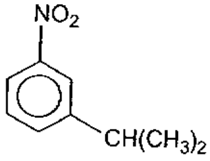
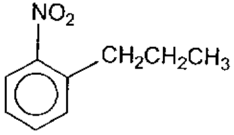
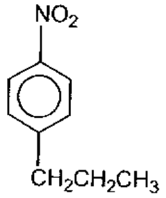
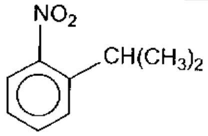
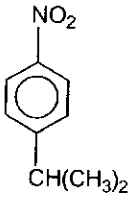
(c) Propene can undergo protonation by an acid to give a mixture of two carbocations that co-exist in equilibrium:

equation 5.1

carbocation **G1** carbocation **G2**

When the equilibrium mixture of the two carbocations was added to nitrobenzene, the following products were obtained.

		
	H	**I**
percentage in product mixture:	29%	70%

			
J	**K**	**L**	**M**

these four were obtained in trace quantities

(i) Suggest a reason why **J**, **K**, **L** and **M** were obtained in trace quantities only.

....

....

....

[1]

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(ii) By considering the position of equilibrium for equation 5.1, suggest why **I** was obtained in larger quantity than **H**.

....

....

....

[1]

(iii) Describe the mechanism for the formation of **I** from nitrobenzene.
In your answer, show any relevant charges, dipoles or lone pairs of electrons you consider important in this mechanism.

[3]

(iv) **H** can be reduced to 3-propylphenylamine.

Suggest a suitable reagents and conditions for this reaction.

....

....

[1]

[Total : 17]

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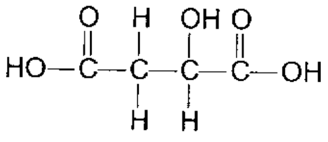
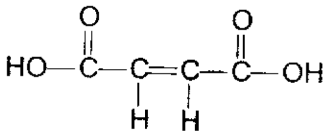
6 Bubble tea is a popular beverage in Singapore. NJC Chemistry department has conducted extensive studies on the effect of bubble tea on health.

(a) Bubble tea drinks are acidic in nature due to the presence of acids such as malic acid. Malic acid can undergo an elimination reaction to produce but-2-enedioic acid.



malic acid



but-2-enedioic acid.

The mechanism of the elimination reaction occurs in three steps.

Complete the mechanism in Fig. 6.1 by showing clearly lone pair electrons and movement of electrons by curly arrows.

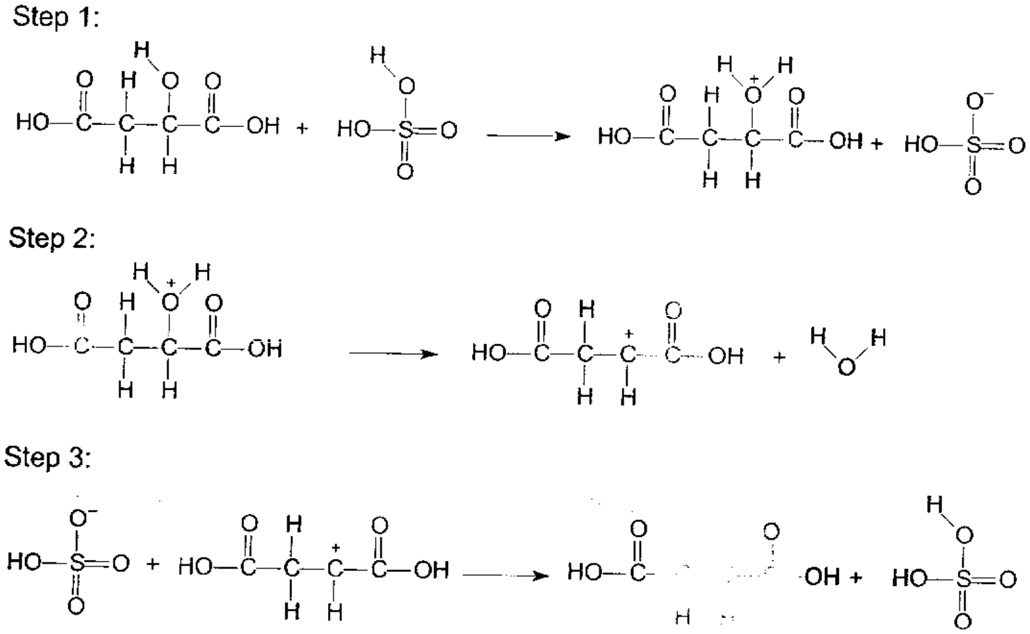


Fig. 6.1

[3]

(b) But-2-enedioic acid exhibits cis-trans isomerism.

	pK_{a1}	pK_{a2}
maleic acid (cis-isomer)	1.9	6.0
fumaric acid (trans-isomer)	3.0	4.4

(i) Draw the monoanion of the two isomers.

monoanion of maleic acid	monoanion of fumaric acid

[1]

(ii) Hence or otherwise, explain why pK_{a1} of maleic acid is smaller than that of fumaric acid.

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[2]

[Turn over

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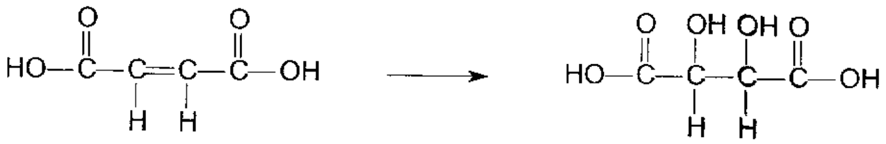
(c) But-2-enedioic acid can be converted to tartaric acid.



$HOOC{-}CH{=}CH{-}COOH \longrightarrow HOOC{-}CH(OH){-}CH(OH){-}COOH$

but-2-enedioic acid tartaric acid

(i) State the reagents and conditions to convert but-2-enedioic acid to tartaric acid.

....

[1]

(ii) But-2-enedioic acid can also undergo an enzyme catalysed reaction to produce tartaric acid.

A reactant in an enzymatic reaction is known as a substrate. The effect of substrate concentration on the rate of reaction is shown in Fig. 6.2.

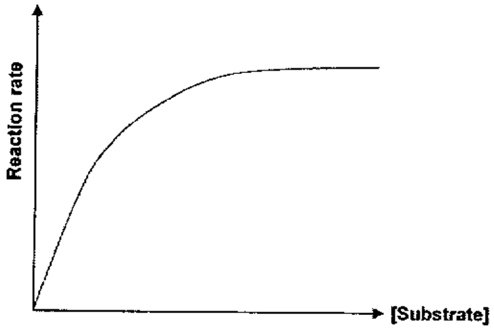


Fig. 6.2

Explain the shape of the graph at low [substrate] and high [substrate].

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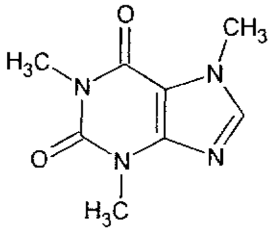
[2]

(d) Bubble tea contains a high amount of caffeine.

Caffeine, a stimulant found in coffee and tea, was discovered by a German chemist, Friedrich Ferdinand Runge, in 1819.

The structure of caffeine is given below.



(i) State the number of sp^2 and sp^3 hybridised carbon atoms in caffeine.

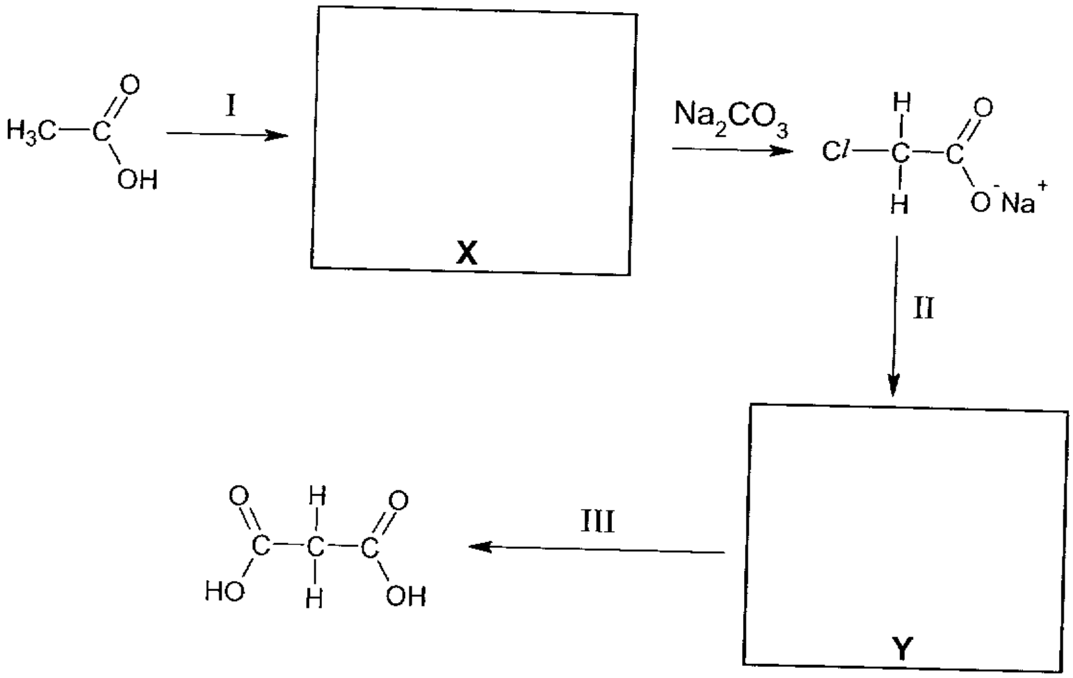
number of sp^2 hybridised carbon atoms : ....

number of sp^3 hybridised carbon atoms : ....

[1]

Caffeine can be synthesised in the laboratory using dimethyl urea, $(CH_3)NHCONH(CH_3)$ and malonic acid, $HOOC(CH_2)COOH$.

Malonic acid is usually prepared from ethanoic acid as follows:



(ii) Draw the structures of the intermediates **X** and **Y**.

[2]

(iii) Suggest reagents and conditions for step I and II and identify the type of reaction for step III in the reaction sequence

Step I : ....

Step II : ....

Type of reaction for step III : ....

[3]

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(e) The caffeine content of some beverages is given in Table 6.1.

Table 6.1

	Red Bull (250 ml)	Coca-Cola (250 ml)	Espresso (60 ml)	Bubble tea (400 ml)
Caffeine content/ mg	80	25	100	160

The beverage consumption pattern of an 18-year-old student was monitored across a 12-hours period. The student followed the instructions and did not consume any caffeine containing products two days prior to the research study.

Time	**Drinks consumed**
0600	Espresso (60 ml)
1000	Coca-Cola (250 ml)
1400	Bubble tea (400 ml)
1800	-

(i) The Singapore Health Promotion Board recommends teenagers' (13-18 years old) total daily caffeine consumption to not exceed 3mg caffeine per kg of body weight.

Given that the student's weight is 54kg, deduce whether the student has exceeded the recommended daily caffeine intake.

[2]

(ii) Caffeine's biological half-life is approximately 4 hours.

Determine the estimated amount of caffeine (in mg) remaining in the student at time 1800. Show your workings clearly.

[2]

[Total : 19]

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