HWA CHONG INSTITUTION
C2 Preliminary Examination
Higher 2

CANDIDATE NAME		**CT GROUP**	2 3 S
CENTRE NUMBER	S	**INDEX NUMBER**	

CHEMISTRY

9729/01

Paper 1 Multiple Choice

16 September 2024

1 hour

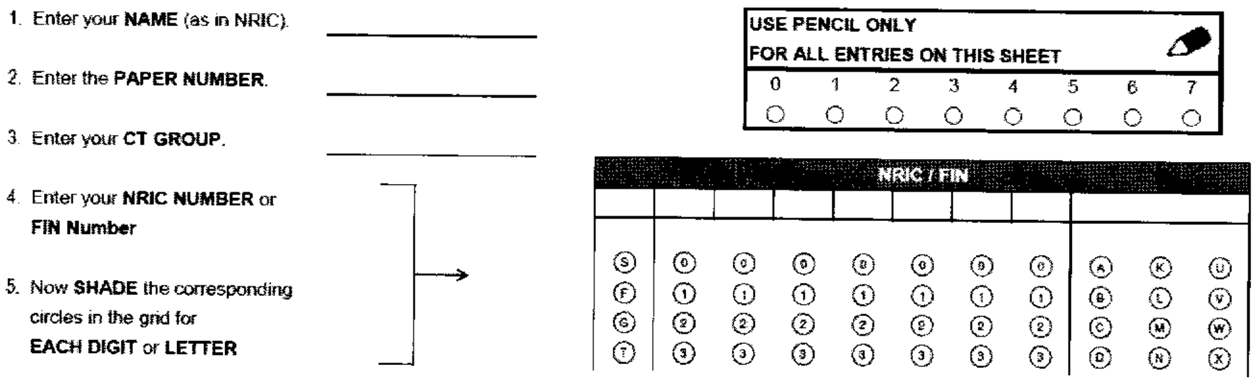
Additional Materials: Multiple Choice Answer Sheet
Data Booklet

READ THESE INSTRUCTIONS FIRST

Write in soft pencil.

Do not use staples, paper clips, glue or correction fluid.

Complete the information on the Answer Sheet as shown below.



1. Enter your **NAME** (as in NRIC).
2. Enter the **PAPER NUMBER**.
3. Enter your **CT GROUP**.
4. Enter your **NRIC NUMBER** or **FIN Number**
5. Now **SHADE** the corresponding circles in the grid for **EACH DIGIT** or **LETTER**

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 **13** printed pages.

1 Heavy water is a form of water whose hydrogen atoms are all replaced by deuterium (^2H), and is used in nuclear reactors.

What are the numbers of electrons and neutrons in D_3O^+?

	electrons	neutrons
A	10	11
B	11	11
C	10	8
D	11	8

2 Which species has two unpaired electrons?

A Li^+ **B** Ti^+ **C** Mg **D** S

3 The Valence Shell Electron Pair Repulsion theory (VSEPR) is used to predict the bond angles of molecules.

Which bond angle is correctly predicted by VSEPR?

	number of bonded electron pairs around central atom	number of lone pairs around central atom	bond angle
A	2	1	105°
B	2	2	118°
C	3	1	107°
D	3	2	90°

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

Some information about the carbonate ion, CO_3^{2-}, is given.

- all carbon-oxygen bonds are of the same length
- π electrons are delocalised throughout the structure

What is the likely carbon-oxygen bond energy, in kJ mol^{-1}, in the carbonate ion?

A 360 **B** 485

C 740 **D** 805

5 Which bonding type corresponds to its description of physical properties?

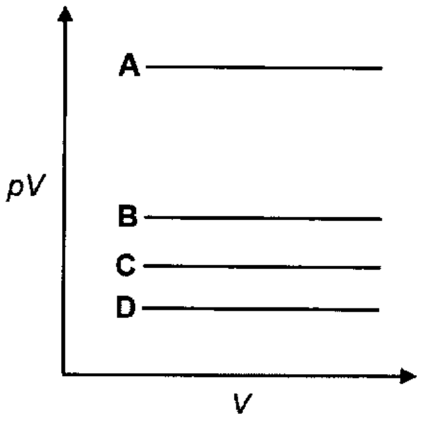
	bonding type	physical properties
1	giant covalent	high melting point, conducts electricity when in solution but not when solid
2	simple covalent	low melting point, does not conduct electricity in any state
3	metallic	variety of melting points, conducts electricity when solid and when molten
4	ionic	low melting point, conducts electricity in any state

A 1 and 2 only **B** 3 and 4 only **C** 2 and 3 only **D** 1 and 4 only

6 The volumes and pressures of equal masses of four gases, nitrogen, methane, chlorine and helium, are separately investigated, at constant temperature.

The results are plotted on a graph of pV against V. All four gases behave as ideal gases under the conditions chosen.

Which plot shows the results for methane?



7 When a sample of a gas is compressed at constant temperature from 15 atm to 60 atm, its volume changes from 76 cm^3 to 20.5 cm^3.

Which statements are possible explanations for this observation?

1 The gas behaves non-ideally.

2 Some of the gas dimerises.

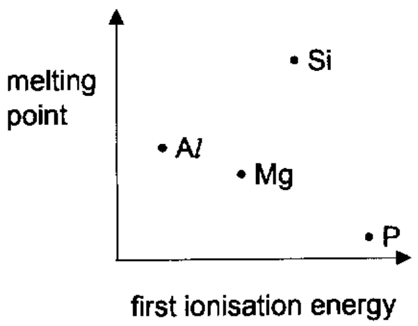
3 There are significant intermolecular forces of attraction between the gas molecules.

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

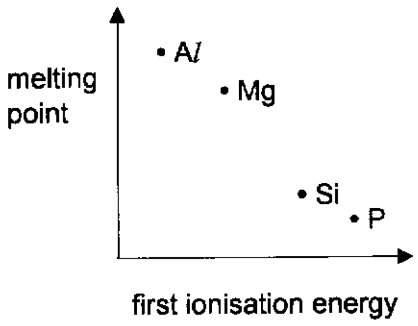
8 *Use of the Data Booklet is relevant to this question.*

Which diagram shows the correct trends when the melting points of the elements Mg, A*l*, Si and P are plotted against their first ionisation energies?

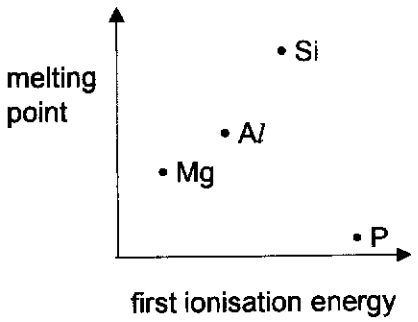
A



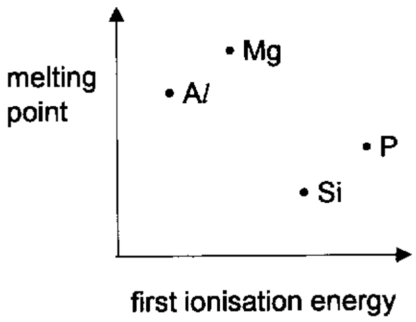
B



C



D



9 Consider the following half equations:

$$Fe^{2+} \rightarrow Fe^{3+} + e^-$$
$$C_2O_4^{2-} \rightarrow 2CO_2 + 2e^-$$

In an experiment, 20 cm³ of an acidified solution of 0.020 mol dm^{-3} of FeC_2O_4 is oxidised by 15 cm³ of 0.020 mol dm^{-3} $KMnO_4$.

What is the final oxidation state of manganese, given that both Fe^{2+} and $C_2O_4^{2-}$ can be oxidised by $KMnO_4$?

A +1 **B** +2 **C** +3 **D** +4

10 Given 1.0 g samples of the same mixture of magnesium carbonate and barium carbonate, which method allows one to determine the mole fraction of magnesium carbonate in the mixture?

1 Add a known volume of 0.1 mol dm^{-3} HC*l*(aq), in excess, and back titrate the excess of acid.

2 Add an excess of HC*l*(aq) and measure, at known temperature and pressure, the volume of CO_2 liberated.

3 Add an excess of HC*l*(aq) followed by an excess of H_2SO_4(aq); filter, dry and weigh the precipitate.

A 3 only

B 1 and 2 only

C 2 and 3 only

D 1, 2 and 3

11 Which enthalpy change is always exothermic?

A lattice energy

B bond breaking

C ionisation energy

D electron affinity

12 The hydrolysis of sucrose in aqueous solution is catalysed by H$^+$(aq) ions, for example, from hydrochloric acid.

$$\text{sucrose} \xrightarrow{H^+(aq)} \text{glucose} + \text{fructose}$$

Which procedure can be used to determine the order of reaction with respect to H$^+$(aq) ions?

A Measure the change in pH during the reaction.

B Remove samples at various time intervals, quench using excess water, then titrate against a standard solution of sodium hydroxide.

C Add a suitable acid-base indicator and watch for the time when the colour changes.

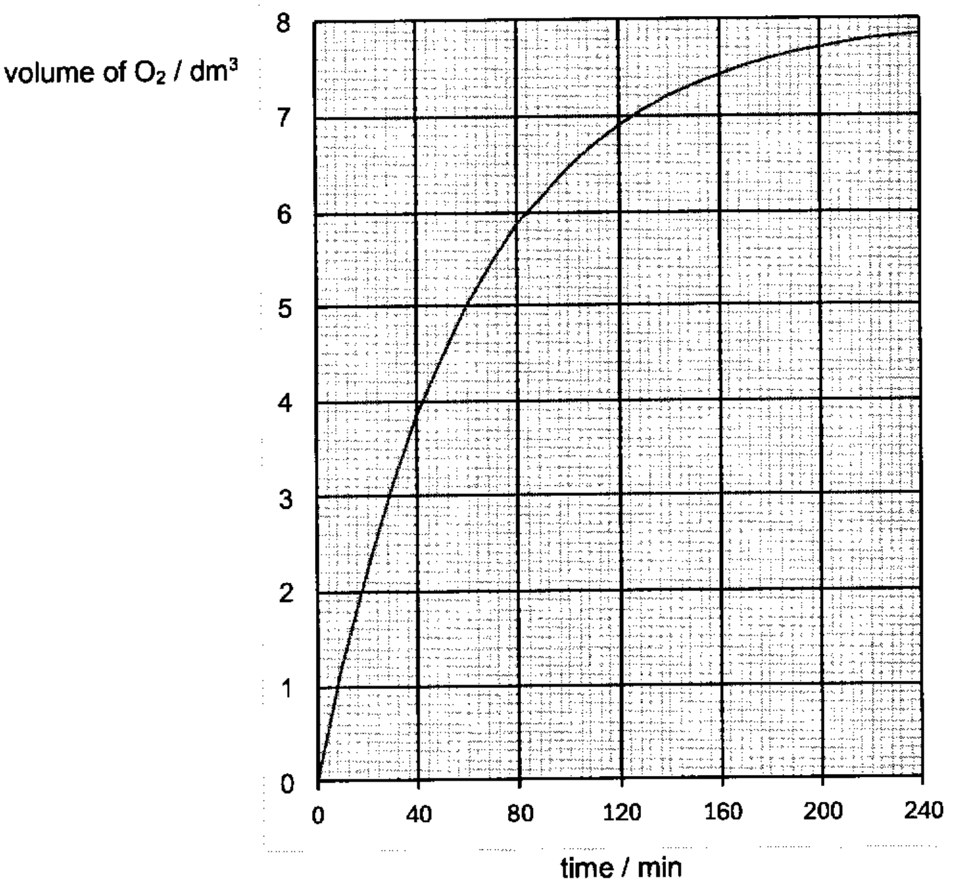
D Measure the time taken for a fixed amount of sucrose to be consumed in the presence of different concentrations of hydrochloric acid each time.

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

Hydrogen peroxide solution decomposes. The equation for this reaction is shown.

$$2H_2O_2(aq) \rightarrow 2H_2O(l) + O_2(g)$$

A 280 cm^3 sample of 2.38 mol dm^{-3} hydrogen peroxide solution is warmed. The volume of oxygen gas collected over time, measured at r.t.p., is recorded in the graph below.



Which statements are correct?

1 The total volume of oxygen gas collected at the end of the reaction is 8.0 dm^3.

2 The rate constant for this reaction is 0.017 min^{-1}.

3 The half-life for the reaction will be about 20 min if initial concentration is 1.19 mol dm^{-3}.

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

14 Which statement about the Haber process for the manufacture of ammonia is correct?

A At higher temperatures, the yield goes up and the rate of production of ammonia is faster.

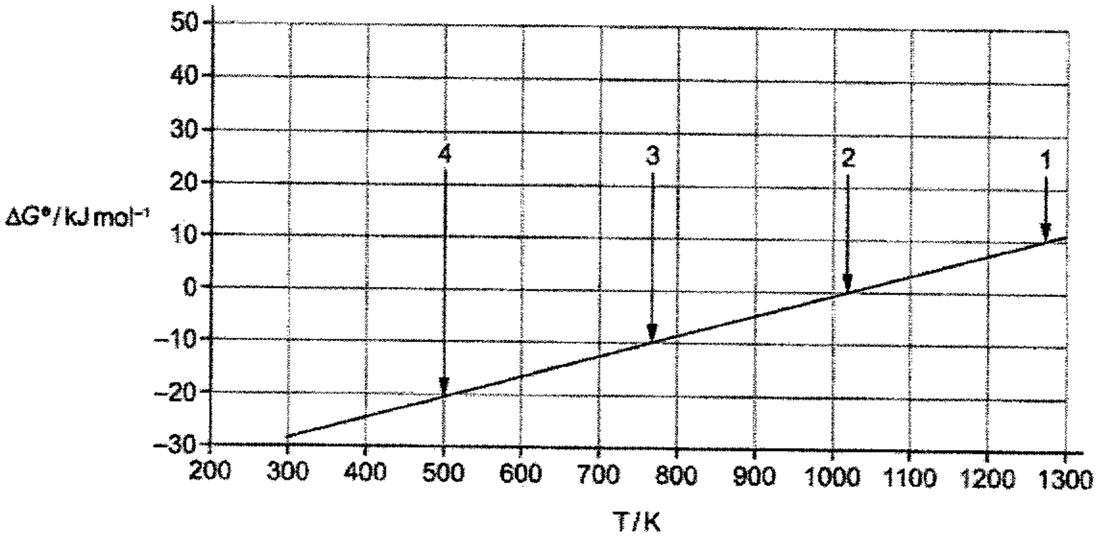
B At higher pressure, the yield goes up and the rate of production of ammonia is faster.

C In the presence of a catalyst, the yield goes down but the rate of production of ammonia is faster.

D When more nitrogen is added, the yield goes down but the rate of production of ammonia is faster.

15 The graph shows how $\Delta G^{\ominus}$ changes with temperature for the reaction shown.

$$H_2O(g) + CO(g) \rightleftharpoons H_2(g) + CO_2(g)$$



Equimolar amounts of H_2O and CO were introduced into a sealed container and allowed to reach equilibrium.

Which statement about this equilibrium is true?

A The concentration of CO_2 is greater than the concentration of H_2O at point 1.

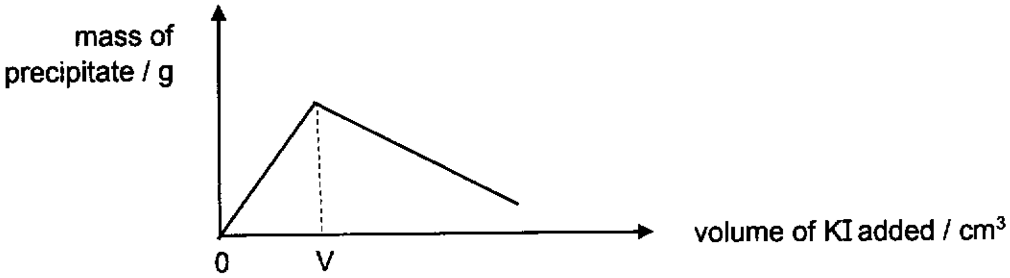
B The concentration of CO_2 is greater than the concentration of H_2O at point 2.

C The concentration of H_2 is greater than the concentration of CO_2 at point 3.

D The concentration of H_2 is greater than the concentration of CO at point 4.

16 When a solution of potassium iodide, KI, was added to a solution of lead(II) nitrate, a bright yellow precipitate, PbI_2, was formed.

A sketch of the mass of precipitate formed against the volume of the KI solution added is shown below.



Which statements can be used to explain the shape of the graph beyond V cm^3?

1 Lead(II) nitrate is the limiting reagent.

2 The position of equilibrium of $PbI_2(s)$ □ $Pb^{2+}(aq) + 2I^-(aq)$ shifts right.

3 PbI_2 reacts with excess KI to form a complex, PbI_4^{2-}.

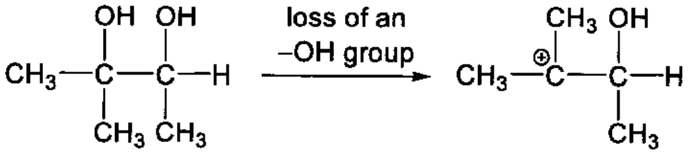
A 3 only **B** 1 and 2 only **C** 2 and 3 only **D** 1, 2 and 3

17 How many constitutional isomers are possible for $C_4H_{10}O$?

A 5 **B** 6 **C** 7 **D** 8

18 The pinacol rearrangement is a method for converting a 1,2-diol to an aldehyde or ketone. An example is shown below using 2-methylbutane-2,3-diol.

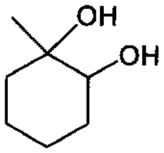
stage 1:



stage 2:

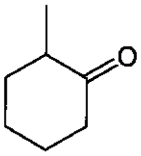
Stage 1 favours the production of a more stable carbocation. This is followed by the migration of an alkyl group in stage 2.

What is the major product when Q undergoes the pinacol rearrangement?

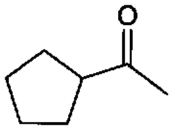


Q

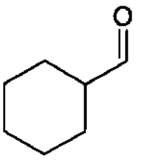
A



B



C



D

19 Which statement regarding the free radical substitution of methylcyclohexane is correct?

A Hydrogen gas is a product.

B Ignoring stereoisomers, there are seven possible monosubstituted products.

C Two of its monosubstituted products are chiral.

D Z can be formed as one of its termination products.

Z

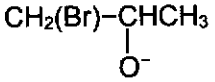
20 What is the intermediate that leads to the major product in the reaction between propene and aqueous bromine?

A $CH_2(Br)-CHCH_3$

B $\overset{+}{C}H_2-CH(Br)CH_3$

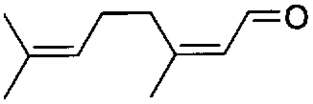
C $\overset{+}{C}H_2-CH(OH)CH_3$

D



$CH_2(Br)-\underset{O^-}{\underset{|}{C}}HCH_3$

21 Citral is present in the volatile oils of several plants.



citral

Which statements about citral are correct?

1 It gives a positive test with ammoniacal silver nitrate.

2 Carbon dioxide is produced when citral is heated with acidified potassium manganate(VII).

3 The number of sp^3-hybridised carbon atoms is equal to the number of sp^2-hybridised carbon atoms in the citral molecule.

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

22 Which statement about benzene reacting with concentrated HNO_3 is correct?

A Electrons in the π electron cloud are donated to a nucleophile.

B Electrons in the carbon-carbon σ bond are donated to an electrophile.

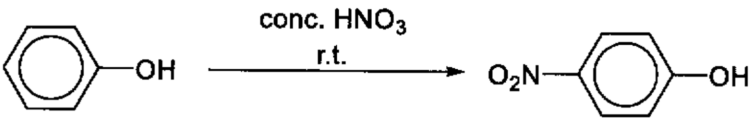
C The hybridisation state of all the carbon atoms of benzene remains unchanged at every step of the reaction.

D Benzene undergoes a substitution reaction so that the delocalised π electron system remains undisrupted at the end of the reaction.

23 Which reaction will give the product indicated?

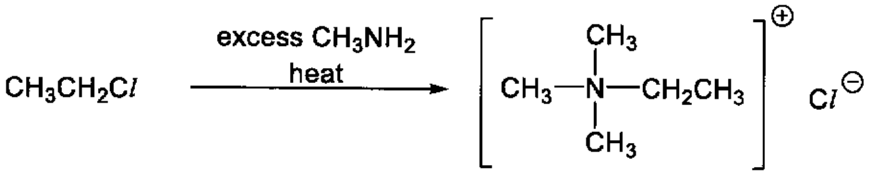
A $CH_3CH_2OH \xrightarrow[\text{heat}]{\text{ethanolic KCN}} CH_3CH_2CN$

B



C $C_6H_5CHBrC(CH_3)_3 \xrightarrow[\text{heat}]{\text{ethanolic KOH}} C_6H_5CH(OH)C(CH_3)_3$

D



24 Which compound gives a yellow solid with warm alkaline aqueous iodine?

A CH_3CHO

B $(CH_3)_3COH$

C $CH_3CO_2CH_3$

D $CH_3CH_2CH_2CHO$

25 The following three compounds are present in a sample in the ratio X : Y : Z = 1 : 1 : 2.

X $HO_2CCH_2CH_2CH{=}CHCO_2H$

Y $CH_3CH_2CH_2CH_2CH{=}CHCOCH_3$

Z $CH_3CH_2CH_2CH_2CH{=}CHCH{=}CHCHO$

How many hydrogen atoms would be incorporated on average per molecule when the sample is reacted with excess $LiAlH_4$?

A 1.50 **B** 2.50 **C** 2.67 **D** 5.50

26 Four compounds are shown below.

$ClCH_2CH_2CO_2H$	$ClCH(CH_3)CO_2H$	$H_2NCH(CH_3)CO_2H$	$CH_3CH_2CO_2H$
I	II	III	IV

What is the correct order in terms of increasing acid strength of the carboxylic acid group?

A III < IV < I < II **B** IV < I < II < III

C III < IV < II < I **D** IV < II < I < III

27 The same carboxylic acid is obtained either by the hydrolysis of a nitrile **P** or by the oxidation of an alcohol **Q**.

What could be **P** and **Q**?

	P	**Q**
A	CH_3CH_2CN	CH_3CH_2OH
B	CH_3CH_2CN	$CH_3CH_2CH(OH)CH_3$
C	$(CH_3)_2CHCN$	$(CH_3)_3COH$
D	C_6H_5CN	C_6H_5OH

28 Which statements are correct about the reaction between ethylamine and ethanoyl chloride?

1 During the reaction, a carbon-chlorine bond is broken and a carbon-nitrogen bond is formed.

2 The same reaction will take place if ethanoyl chloride is replaced by ethanoic acid.

3 The organic product formed, when dissolved in water will give a solution that has a pH greater than 7.

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

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

When the Fe^{3+}/Fe^{2+} half cell in standard conditions is joined to a standard hydrogen electrode, the $E^{\ominus}_{cell} = +0.77V$.

Which changes to the cell conditions would lead to a lower cell potential?

1 Adding water into the Fe^{3+}/Fe^{2+} half cell.

2 Increasing the pressure of $H_2(g)$.

3 Adding an excess of $CN^-(aq)$ into the Fe^{3+}/Fe^{2+} half cell.

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

30 Transition metal ions can react in a number of different ways. Listed are four different reactions of transition metal ions with relevant observations.

Which observation does **not** involve ligand exchange?

A When a purple solution of chromium(III) sulfate is warmed, a green solution containing $[Cr(H_2O)_5SO_4]^+$ is formed.

B When an excess of aqueous ammonia is added to a solution of cobalt(II) chloride, a brown solution of $[Co(NH_3)_6]^{3+}$ ions is made.

C When an excess of aqueous sodium hydroxide is added to a solution of iron(III) chloride, a reddish-brown precipitate of $Fe(OH)_3$ is formed.

D When concentrated hydrochloric acid is added to a blue-green solution of aqueous copper(II) chloride, a yellow solution of aqueous $[CuCl_4]^{2-}$ is formed.

HWA CHONG INSTITUTION
2024 C2 H2 CHEMISTRY PRELIMINARY EXAMINATION
SUGGESTED SOLUTIONS

Paper 1

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

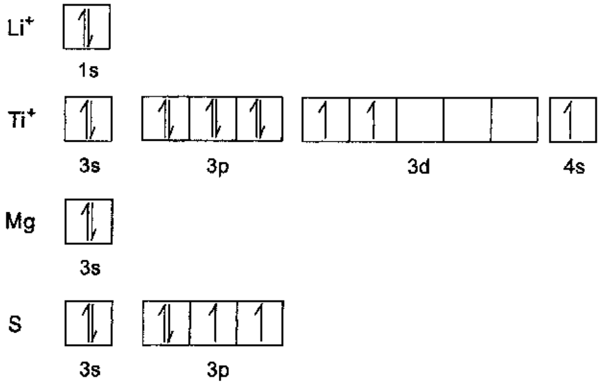
Comments

1 **A** ^{2}H has 1 proton, 1 electron and 1 neutron.
^{16}O has 8 protons, 8 electrons and 8 neutrons.

For D_3O^+,
Number of neutrons = 1 + 1 + 1 + 8 = 11

Since D_3O^+ is cationic, it is short of 1 electron overall.
Number of electrons = 1 + 1 + 1 + 8 – 1 = 10

2 **D** Here are the electron-in-box diagrams of the valence orbitals in each species.



Only sulfur has 2 unpaired electrons in its electronic configuration.

3 **C** Based on the number of bond pairs and lone pairs listed in the question, these are the corresponding geometries and bond angles:
A: Bent, 118°
B: Bent, 104.5°
C: Trigonal pyramidal, 107°
D: T-shaped: 88°

4 **B** Since electrons are delocalised in the carbonate ion, there is partial double bond character, and the bond length is likely to be between a C–O bond and a C=O bond.

From *Data Booklet*, the average C–O bond energy is 360 kJ mol^{-1} while the average C=O bond energy is 740 kJ mol^{-1} thus it is likely that the C–O bond energy in carbonate is 485 kJ mol^{-1}.

5 **C**

	bonding type	physical properties
1	giant covalent	high melting point, ~~conducts electricity when in solution but not when solid~~ does not conduct electricity in any state.
2	simple covalent	low melting point, does not conduct electricity in any state
3	metallic	variety of melting points, conducts electricity when solid and when molten
4	ionic	~~low melting point~~ high melting point, ~~conducts~~ does not conduct electricity in any state.

6 **B** The ordinate (i.e. y-coordinate) is PV = nRT = mRT/M_r = constant / M_r

Hence the y-value of the graph is inversely proportional to the molar mass of the gas. In order of increasing molar mass, the gases are helium (M_r = 4.0), methane (M_r = 16.0), nitrogen (M_r = 28.0) and chlorine (M_r = 71.0). Hence the graph for methane should be the second highest horizontal line (i.e. second largest y-value).

7 **A** The gas is compressed to a pressure 4 times its original. If the gas were an ideal gas, its new volume would be expected to be one-quarter of its original, i.e. 19.0 cm^3. However, its new volume was 20.5 cm^3, so the gas did not behave ideally. The gas could not have dimerised, as the number of moles of gas would have decreased and the final volume would have been smaller than 19.0 cm^3.

Option **3** also does not explain the observation, as the presence of significant intermolecular forces of attraction would have also caused the actual volume to be smaller than 19.0 cm^3.

8 **A** First, use the Data Booklet to find the first ionisation energies of the elements.

	1st IE / KJ mol^{-1}
Mg	*736*
Al	*577*
Si	*786*
P	*1060*

From this data, *Al* will be the leftmost on the x-axis while P will be the rightmost on the x-axis. Option **C** will be eliminated at this point. Option **A**, **B** and **D** are possible.

The melting point of Si will be the highest among the 4 while P has the lowest. Hence on the y-axis Si will be the highest point while P is the lowest point.

Only Option A fits both sets of data and is the correct answer.

FYI: Melting points of the following Period 3 elements are as follows.

	mp / °C
Mg	*659*
Al	*703*
Si	*1410*
P	*44*

9 **C** No. of moles of FeC_2O_4 = 0.020 × 0.020 = 0.000400 mol

No. of moles of $KMnO_4$ = 0.015 × 0.020 = 0.000300 mol

No. of moles electrons transferred = 0.000400 × 3 = 0.00120 mol

No. of moles of MnO_4^- : No. of moles of electrons = 0.000300 : 0.00120 = 1:4

Each mole of MnO_4^- takes in 4 moles of electrons.
Hence the oxidation number of Mn changes from +7 to +3.

10 **D** Options **1** and **2** allow us to determine the total number of moles of carbonates in the sample. Since the mass of the sample is known, we can then solve for the mole fraction of magnesium carbonate using the molar masses of the two carbonates.

For option **3**, $BaSO_4$ is collected as a precipitate, allowing us to determine the number of moles of barium carbonate. We can then calculate the mass of barium carbonate, mass of magnesium carbonate and number of moles of magnesium carbonate.

11 **A** The only enthalpy change that is always exothermic in the list provided is the lattice energy as it is a process that forms ionic bonds.

Bond breaking and ionisation energy are both endothermic processes.

As for electron affinity, 1st electron affinity to form monoanions are exothermic, but 2nd electron affinity and beyond are endothermic processes.

12 **D** $[H^+]$ will remain constant as it is the catalyst. Hence methods that measure changes in $[H^+]$ (options **A**, **B** and **C**) are not suitable for monitoring the reaction.

Experiments that use different $[H^+]$ have to be set up in order to determine the order for H^+ (option **D**).

13 **B** From the given data, the maximum volume of oxygen that can be collected at the end of the experiment = $2.38 \times \frac{280}{1000} \times \frac{1}{2} \times 24 = 8.0$ dm^3. Option **1** is correct.

From the graph, first $t_{1/2}$ is found from 0 to 4.0 dm^3 (50% of 8.0), which is 42 min. The second $t_{1/2}$ is found from 4.0 dm^3 to 6.0 dm^3 (75% of 8.0), which is also 42 min. Hence the reaction is first order with respect to hydrogen peroxide and is also overall first order. The rate constant of an overall first order reaction is $k = \frac{\ln 2}{t1/2}$. Hence the value of rate constant, $k = \frac{\ln 2}{42} = 0.017$.

For a first order reaction, rate = k[A].
The units of rate constant = $\frac{mol\ dm{-}3\ min{-}1}{mol\ dm{-}3}$ = min^{-1} Option 2 is correct.

For a first order reaction, half-life is independent of initial concentration of hydrogen peroxide. Hence option C is wrong as it should have remained at 42 min.

14 **B** The Haber process is used to manufacture ammonia from nitrogen and hydrogen.

$$N_2(g) + 3H_2(g) \rightleftharpoons 2NH_3(g) \qquad \Delta H_r < 0$$

When temperature increases, the backward endothermic reaction will be favoured, leading to a decrease in yield. Hence **A** is wrong.

High pressure favours the forward reaction as it reduces the number of moles of gases. In addition, rate increases as the frequency of effective collisions increases. Thus **B** is correct.

The presence of a catalyst only affects the rate of reaction but not the position of equilibrium, so **C** is wrong.

The introduction of more nitrogen will favour the forward reaction, causing an increase in the yield. Hence **D** is wrong.

15 **D** A negative value for $\Delta G^\ominus$ represents a driving force in the forward direction, and position of equilibrium lies to the right.

A positive value for $\Delta G^\ominus$ represents a driving force in the reverse direction, and position of equilibrium lies to the left.

For point 4, the position of equilibrium lies to the right, which means that the concentration of H_2 should be higher than the concentration of CO.

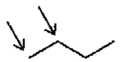
16 **C** Option **1** is incorrect. If lead(II) nitrate is limiting, the mass of precipitate should remain constant beyond V.

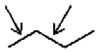
Option **2** is correct. When more KI is added, a soluble lead iodide complex is formed. This decreases the concentration of $Pb^{2+}(aq)$ in solution, causing the position of equilibrium of $PbI_2(s) \rightleftharpoons Pb^{2+}(aq) + 2I^-(aq)$ to shift right, and mass of the precipitate will decrease.

Option **3** is correct. The formula of the soluble lead complex is PbI_4^{2-}.

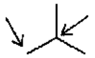
17 C

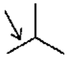
start with 4C **<u>linear</u> chain:**


putting one –OH group on either of these two carbons gives 2 isomers


inserting one O atom at either of these positions gives 2 isomers

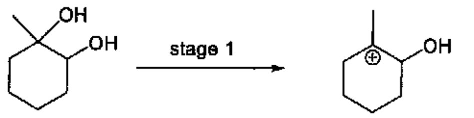
then <u>branch</u> the 4C chain:


putting one –OH group on either of these two carbons gives 2 isomers


inserting one O atom at this position gives 1 isomers

Total = 7 constitutional isomers

18 D

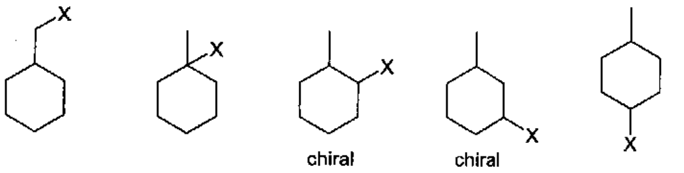
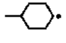
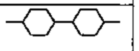


more stable carbocation

migration of the alkyl group

formation of a 5-membered ring, with a $-C_aHO$ group on C5

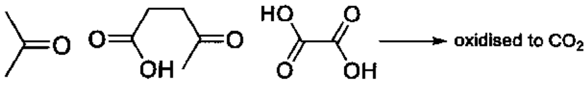
19 C

A	H• radicals are not produced in the propagation steps, so no H_2 can form in the termination step. Incorrect.
B	Incorrect. There are only five monosubstituted products as shown below. 
C	Only two of the monosubstituted products above are chiral. Correct.
D	Z only has 9 carbon atoms. If two  radicals combine,  should be obtained instead.

20 A The reaction between propene and aqueous bromine is an electrophilic addition. In the first (slow) step of the mechanism, the bromine electrophile adds to one of the C=C carbons, forming an intermediate carbocation. Hence options **C** and **D** are incorrect.

Comparing intermediates A and B, the former is favoured as it is a secondary carbocation, which is more stable than the latter, a primary carbocation. Carbocation A is attacked by a water molecule in the second step, leading eventually to the bromoalcohol major product.

21 D Option **1** is correct as there is an aldehyde group in the citral molecule, which will give a silver mirror with Tollens' reagent (ammoniacal silver nitrate). Option **2** is correct as citral undergoes oxidation/oxidative cleavage to give the following products:



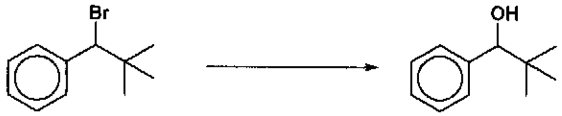
Option **3** is correct as all 5 carbons at a double bond are sp^2-hybridised, whereas all 5 other carbons are sp^3-hybridised.

22 D Electrons are donated to an electrophile and not a nucleophile.

Electrons in the π electron cloud are donated to the electrophile, not from the σ bond.

When electrophilic substitution occurs, the hybridisation state of the carbon undergoing the reaction changes from sp^2 in benzene, to sp^3 in the intermediate, and back to sp^2 again when the benzene ring is reformed.

23 C

A	Alcohols do not react with KCN.
B	Phenol's benzene ring is strongly activated by the –OH group and will undergo tri-substitution when concentrated nitric acid is used.
C	The given bromoalkane does not have any –CH adjacent to the C–Br carbon, and hence cannot undergo elimination with ethanolic KOH. Nucleophilic substitution may occur using OH^- nucleophile to produce the alcohol shown. 
D	Excess of the chloroalkane is needed for multiple substitution to give the quaternary ammonium salt. The reaction stops once all the chloroethane has reacted to give the secondary amine, as there is no more electron deficient carbon for the excess methylamine nucleophile to attack. $CH_3CH_2Cl + CH_3NH_2 \rightarrow CH_3CH_2NHCH_3 + HCl$

24 **A** Alcohols with $CH_3CH(OH)-$ structure or ketones with CH_3CO- structure or ethanal (CH_3CHO) give a positive iodoform test (yellow solid produced). Options B, C and D do not have any of these relevant structures, hence are incorrect. Although option C has the CH_3CO- structure, it is not a ketone but rather an ester, hence gives a negative iodoform test.

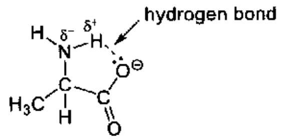
25 **B** $LiAlH_4$ does not react with alkenes. It reduces carboxylic acid (RCO_2H) to primary alcohol (RCH_2OH), which is a gain of 2H and loss of 1O. It reduces aldehyde ($RCHO$) to primary alcohol (RCH_2OH) which is a gain of 2H. It also reduces ketone ($RCOR$) to secondary alcohol ($RCH(OH)R$) which is a gain of 2H.

Hence X (a dicarboxylic acid), Y (a ketone) and Z (an aldehyde) will have 4, 2 and 2 hydrogen atoms incorporated respectively after reacting with $LiAlH_4$. Considering that X, Y and Z are present in 1:1:2 ratio, the average number of hydrogen atoms incorporated per molecule is $(4+2+2+2)\div4 = 2.50$.

26 **B** The $-Cl$ and $-NH_2$ groups in I, II and III are all electron-withdrawing groups which help to disperse the negative charge on the carboxylate ion, thereby stabilising the corresponding conjugate bases formed. Hence, IV is the least acidic as its carboxylate ion is the least stable.

Students who choose options **A** or **C** wrongly thought that the $-NH_2$ group in III is electron-donating. The lone pair on the nitrogen of this $-NH_2$ group cannot be delocalised over to the $-CO_2^-$ group in the conjugate base, as the $-NH_2$ group is bonded to an sp^3 carbon (which thus would not have any unhybridised p orbital for lone pair on the $-NH_2$ nitrogen to be delocalised).

Comparing I, II and III, the $-NH_2$ group is a stronger electron-withdrawing group than $-Cl$ (as N is more electronegative than Cl). The carboxylate ion of III can also be stabilised via an internal hydrogen bond as shown below. III is hence the most acidic as its conjugate base is the most stable.



Comparing I and II, the electron-withdrawing $-Cl$ disperses the negative charge on the carboxylate ion of I less effectively than that of II, as the electron-withdrawing effect weakens with distance. Conjugate base of I is less stable, so I is less acidic than II.

27 **B**

A	This pair of compounds do not have the same number of carbon atoms.
B	The alcohol can undergo a reaction with alkaline aqueous iodine to form the same carboxylic acid as the nitrile. Note that the reaction with aqueous alkaline iodine is an oxidation reaction.
C	The alcohol is a tertiary alcohol that will not undergo oxidation to form a carboxylic acid.
D	Phenols are not able to undergo oxidation to form carboxylic acids.

28 **A** The reaction between ethanoyl chloride and ethylamine leads to the formation of an amide. Option **1** describes one of the key bond formed and broken in the course of the reaction.

When ethanoyl chloride is replaced by ethanoic acid, an acid base reaction will take place instead of nucleophilic acyl substitution. So option **2** is incorrect.

The amide formed is neutral and the pH of the solution should therefore be 7. So option **3** is incorrect.

29 **B** Cell potential = $E^\ominus_{Fe^{3+}/Fe^{2+}} - E^\ominus_{H^+/H_2} = +0.77 - 0.00 = +0.77V$

When water is added into the Fe^{3+}/ Fe^{2+} half-cell, both Fe^{3+} and Fe^{2+} will be diluted by the same extent. There is no change in the position of equilibrium for the half cell. Thus the cell potential will remain unchanged.

Should the pressure of $H_2(g)$ increase, the position of equilibrium for the hydrogen electrode will shift to favour the oxidation of H_2, making the $E_{(H+/H2)}$ negative and thus the cell potential will be more positive.

When excess CN^- is added into the Fe^{3+}/ Fe^{2+} half-cell, ligand exchange will occur and all the Fe^{3+} and Fe^{2+} will form their respective complex ions with CN^-. The new E is (close to) +0.36V leading to a lower cell potential.

30 **C** Option **A** involves SO_4^{2-} ligands replacing H_2O ligands in $[Cr(H_2O)_6]^{2+}$.

Option **B** involves NH_3 ligands replacing H_2O ligands in $[Co(H_2O)_6]^{2+}$, followed by oxidation.

Option **C** involves step-wise deprotonation of H_2O ligands due to high charge density of Fe^{3+} rather than ligand exchange.

Option **D** involves Cl^- ligands replacing H_2O ligands in $[Cu(H_2O)_6]^{2+}$.