CJC Viller * county
ATE ST

Catholic Junior College

JC 2 Preliminary Examinations Higher 2

CANDIDATE
NAME

CLASS

CHEMISTRY

Paper 1 Multiple Choice

9729/01 12 September 2024 1 hour

Additional Materials: Multiple Choice Answer Sheet Data Booklet

READ THESE INSTRUCTIONS FIRST

2T

Write in soft pencil.

Do not use staples, paper clips, glue or correction fluid. Write your name, class and NRIC/FIN number on the Answer Sheet in the spaces provided.

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.

WORKED SOLUTIONS

This document consists of 28 printed pages.

- 1 Which of the following statements about the properties associated with ionic and covalent bonds is correct?
 - A The only covalent compounds with high melting points are those in which hydrogen bonds occur.
 - **B** Any covalent compound that contains both oxygen and hydrogen in its molecule forms hydrogen bonds.
 - **C** Both ionic bonds and covalent bonds cannot occur in the same compound.
 - D lonic compounds differ from metals in that ionic compounds do not conduct electricity in the solid state.

2 Which of the following shows the correct shape and bond angle of the molecule given?

	molecule	shape	bond angle
Α	OF ₂	bent	117°
В	BH_3	trigonal pyramidal	120°
С	XeF ₄	tetrahedral	109°
D	SF ₆	octahedral	<mark>90°</mark>



9729/01 CJC JC2 Preliminary Examination 2024

3 Thiophenol and phenol are both acting as weak acids in aqueous solutions.



Which statements are correct?

- 1 H⁺ is less easily removed from thiophenol than phenol because the S–H bond is less polar than O–H bond.
- 2 The K_a value is smaller for phenol because the O–H bond is stronger than the S–H bond.
- **3** When pure liquid thiophenol and phenol are mixed together without water, the S–H bond in thiophenol is more likely to dissociate than the O–H bond in phenol.

Α	1, 2 and 3	B 1 and 2	C 2 and 3	D	3 only
---	------------	------------------	-----------	---	--------

Topic: Chemistry of Aqueous Solutions

I

1

I I

Т

1

From pK_a values, thiophenol is a stronger acid than phenol.

1: Incorrect. H⁺ is more easily removed from thiophenol since it is the stronger acid.

2: Correct. The K_a value for phenol is smaller (10⁻¹⁰) compared to thiophenol (10^{-6.5}). Furthermore O–H bond (460 kJ mol⁻¹) is stronger than S–H bond (347 kJ mol⁻¹), either refer bond energy value from *Data Booklet* or considering shorter O–H bond length due to smaller atomic radius of oxygen.

3: Correct. Given a larger K_a value of thiophenol, the acid dissociation occurs more likely than phenol, and phenol may act as a base.

Answer: C - similar to 2022/P1/Q3

4 The value of pV is plotted against p at the same temperature for four gases, where p is the pressure and V is the volume of the gas.



What are the possible identities of Gas 1, 2, 3 and 4?

	Gas 1	Gas 2	Gas 3	Gas 4
Α	He	CH₃F	HF	H ₂ O
В	He	HF	CH₃F	H ₂ O
С	H ₂ O	He	CH₃F	HF
D	<mark>H₂O</mark>	HF	<mark>CH₃F</mark>	He

Topic: The Gaseous State Extent of deviation from ideal gas behaviour: $H_2O > HF > CH_3F > He$ Both H_2O and HF form intermolecular hydrogen bonding. H_2O has more extensive intermolecular hydrogen bonding than that of HF. Hence. H_2O deviates more from ideality. H_2O and HF (with stronger intermolecular hydrogen bonding) deviates more from ideality than CH_3F (with weaker intermolecular permanent dipolepermanent dipole attractions). CH_3F (with stronger intermolecular permanent dipolepermanent dipole-induced dipole attractions).

Answer: D

5 The graph below shows the melting points of four consecutive Period 3 elements **W** to **Z**.



Which of the following graphs represents the correct trend of the stated property for W to Z?









6 To obtain the magnesium present in a mineral ore filled with impurities of Al_2O_3 and P_4O_{10} , which of the following reagents could be used to dissolve the impurities in the ore?

- B dilute HCl
- C dilute HNO₃
- D dilute NaOH



7 Carbon monoxide, CO, is a colourless, odourless and toxic gas. The maximum safe toleration level of CO in air is 50 ppm. (1 ppm = 1 mg of CO in 1 kg of air)

How many CO molecules are present in 1 kg of air at this maximum safe toleration level?



8 Figure 1 shows the first eight ionisation energies, log (IE), of an element **J** while Figure 2 shows the boiling point of eight consecutive elements (including element **J**).



Figure 2



With reference to Figure 2, which of the options **A**, **B**, **C** or **D** corresponds to the boiling point of element J?



9 Which of the following ions has more electrons than protons and more protons than neutrons? $[H = \frac{1}{1}H; D = \frac{2}{1}H; C = \frac{12}{6}C; O = \frac{16}{8}O]$

3 H_2DO^+ C O_3^{2-}					
"more electro "more protor (D, C, and O I	ons that is than have the	n protons" \Rightarrow neutrons" \Rightarrow same no. of p	it must be neg it must contai rotons and neg	jatively charge n H utrons)	Electrone
"more electro "more protor (D, C, and O I	ons than than have the	n protons" ⇒ neutrons" ⇒ same no. of p Species	it must be neg it must contai rotons and net Protons o	atively charge n H utrons) Neutrons	Electrons
"more electro "more protor (D, C, and O I	ons than than the the A B	n protons" ⇒ neutrons" ⇒ same no. of p Species OH ⁻ H ₂ DO ⁺	it must be neg it must contai rotons and net Protons 9 11	atively charge n H utrons) Neutrons 8 9	Electrons
"more electro "more protor (D, C, and O I	ns than the sthan ave the A B C	n protons" ⇒ neutrons" ⇒ same no. of p Species OH ⁻ H ₂ DO ⁺ CO ₃ ²⁻	it must be neg it must contai rotons and net Protons 9 11 30	atively charge n H utrons) Neutrons 8 9 30	ed Electrons 10 10 32

10 A student dissolved 0.238 mol of sodium fluoride in 300 cm³ of water. Given the following data:

Lattice energy of NaF	−918 kJ mol ⁻¹
Enthalpy change of hydration of F ⁻	−457 kJ mol ⁻¹
Enthalpy change of hydration of Na ⁺	−390 kJ mol ⁻¹

What would be the initial temperature, in °C, of the water if the final temperature of the solution is 20.0 °C?

(Assume that the specific heat capacity of sodium fluoride solution is 4.18 J g^{-1} K⁻¹)

A 6.5 B 13.5 C 26.5 D 33.5
Topic: Chemical Energetics Part 1 (Enthalpy Change)

$$\Delta H_{sol} = -LE + \Delta H_{hyd} = -(-918) + (-457) + (-390)$$

$$= + 71.0 \text{ kJ mol}^{-1} \text{ (endothermic reaction)}$$
Heat absorbed, q = 71.0 x 0.238 = 16.898 kJ

$$\Delta T = \frac{q}{mc} = -\frac{16898}{300 (4.18)} = 13.5 \text{ K (or °C)}$$
Initial temperature = 20.0 + 13.5 = 33.5 °C
Answer: D

9729/01 CJC JC2 Preliminary Examination 2024

- 11 Which of the following reactions shows a positive change in entropy?
 - A $N_2O(g) \rightarrow N_2(g) + \frac{1}{2}O_2(g)$
 - **B** Fe(s) + S(s) \rightarrow FeS(s)
 - **C** Ca(s) + $\frac{1}{2}O_2(g) \rightarrow CaO(s)$
 - **D** $C_3H_6(g) + H_2(g) \rightarrow C_3H_8(g)$

Topic: Chemical Energetics Part 2 (Entropy)
Option A: ΔS > 0 as there is an increase in the number of gaseous molecules after the reaction.
Option B: ΔS < 0, as there is no change in the no. of moles of gas. There is a decrease in the number of particles from 2 to 1 in the solid phase.
Option C and D: ΔS < 0, as there is a decrease in the number of gaseous molecules after the reaction.

12 The diagrams P, Q, R and S show how a change in conditions affects the Maxwell-Boltzmann distribution of molecular energies for gas G. In each case, the original distribution is shown by a solid line and the distribution after a change has been made is shown by a dashed line.



Which statement about the change made is correct?

- A The change shown in diagram **P** occurs when the temperature is decreased.
- **B** The change shown in diagram **Q** occurs when more moles of gas is added.
- **C** The change shown in diagram **R** occurs when the temperature is increased.
- **D** The change shown in diagram **S** occurs when a catalyst is added.

Topic: Reaction Kinetics (Maxwell Boltzmann Distribution Curves)
Option A: The change shown in diagram P occurs when the temperature is increased causing a greater spread in molecular energies.
Option C: The change shown in diagram R occurs when the temperature is decreased causing a smaller spread in molecular energies.
Option D: There should be no change to the original distribution shown in diagram S when a catalyst is used.
Option B: When more moles of gas is added at a fixed temperature, this results in an increase in number of gaseous molecules at each energy.
Answer: B

9729/01 CJC JC2 Preliminary Examination 2024

13 The reaction between nitrogen and hydrogen is carried out.

$$N_2(g) + 3H_2(g) \rightleftharpoons 2NH_3(g)$$

In a vessel of volume 2.00 dm³, 6.00 mol of nitrogen and 6.00 mol of hydrogen are mixed. This is allowed to reach equilibrium at a certain pressure and temperature, with a catalyst. At equilibrium, 2.00 mol of NH_3 is present.

What is the numerical value of K_c for this reaction under the conditions used?



14 What is the pH of the final solution when V cm³ of dilute sulfuric acid of pH 1.0 is mixed with V cm³ of dilute hydrochloric acid of pH 3.0 followed by the addition of 2V cm³ of water?

A 1.3 B 1.6 C 2.0 D 2.6
Topic: Chemistry of aqueous solutions
Concept: Calculation of pH of acidic solutions
Total volume of final solution = V + V + 2V = 4V cm³
Total amount of H⁺ ions in final solution =
$$(10^{-1} \times \frac{V}{1000}) + (10^{-3} \times \frac{V}{1000}) mol$$

[H⁺] in final solution = $\frac{(10^{-1} \times \frac{V}{1000}) + (10^{-3} \times \frac{V}{1000})}{\frac{4V}{1000}}$ = 0.02525 mol dm⁻³
pH of final solution = - log (0.02525) = 1.6
Answer: B

15 The following graph represents how the solubility of a sparingly soluble salt lead(II) chloride, $PbCl_2$, changes upon addition of solid potassium chloride, KCl at a fixed temperature.



Which statement about the above graph is incorrect?

A K_{sp} remains constant along P to R.

ľ I

- **B** The change in solubility along P to Q is due to common ion effect.
- **C** At Q, the molar concentration of Cl^{-} ions is twice that of Pb²⁺ ions.
- **D** The change in solubility along Q to R is due to the formation of a complex ion.

Option	Explanation
Α	K _{sp} is only dependent on temperature.
В	As more Cl^- is added, the above equilibrium (1) will shift to the left, causing the solubility of Pb Cl_2 to decrease. This is known as the common ion effect.
С	At Q, the concentration of Cl^- is not necessarily twice that of Pb^{2+} as Cl^- is also contributed by the addition of KC <i>l</i> .
D	Pb ²⁺ (aq) + 4C <i>l</i> ⁻ (aq) ⇒ [PbC <i>l</i> ₄] ²⁻ (aq)
	When even more Cl^- is added, a soluble complex $[PbCl_4]^{2-}$ is formed. The formation of this complex decreases the $[Pb^{2+}]$, causing the above equilibrium (1) to shift to the right. This increases the solubility of $PbCl_2$.

I

1

1

16 A sparingly soluble calcium salt dissociates in solution according to the equation below. $CaX_2(s) \rightleftharpoons Ca^{2+}(aq) + 2X^{-}(aq)$

If the solubility product of CaX_2 is $q \mod^3 dm^{-9}$, what is the concentration of X⁻ at equilibrium in a saturated solution of $CaX_2(aq)$?

Α	$\frac{q}{3}$	$B \qquad 2(\sqrt[3]{\frac{q}{4}})$	С	$\sqrt[3]{q}$	Γ	D	$\sqrt[3]{\frac{q}{4}}$	
To Co	pic: Chemistry o ncept: Solubility	f aqueous solutio VS Solubility Equ	ns (Solu ıilibrium	bility Eq	uilibrium)			
Let	t x represent the	solubility of CaX ₂						
¦ [Ca ¦ [X⁻	$a^{2+}] = x$] = 2 x							
Ksp	$a = [Ca^{2+}] [X^{-}]^2 = (a^{2+}) [X^{-}]^2 = (a$	x)(2x) ²						
4 x	a = q							
[X	[] = 2x							
 	$=2\sqrt[4]{\frac{q}{4}}$							
An	swer: B							

17 Which statements are true regarding the mechanism for the formation of methylbenzene from benzene?



- 1 One carbon on the benzene ring changes from sp² to sp³ and back to sp².
- 2 The number of delocalised electrons in the ring changes from 6 to 5 then back to 6.
- **3** The reaction involves two carbocation intermediates.



9729/01 CJC JC2 Preliminary Examination 2024

18 Certain alkenes can exhibit cis-trans isomerism, and structures of alkenes are shown below.



Which statements are correct?

- **1** There is restricted rotation about the C=C double bond due to the presence of two σ bonds.
- 2 Only one C=C double bond in citral A exhibits cis-trans isomerism.
- 3 Limonene is not able to exhibit cis-trans isomerism.



19 TPI is an enzyme that is essential for energy production. It catalyses the following reaction.



20 The structure of an α -atlantone derivative is shown below.



This derivative is reacted with excess hydrogen gas over a platinum catalyst. How many chiral centres are formed in **this** reaction?



21 Which of the following is **not** formed when but-1-ene reacts with IBr(aq)?





22 2–bromobutane undergoes substitution with KCN in a suitable solvent with the following outcome.



Which statements about this reaction are correct?

- 1 An intermediate is formed which is easily attacked by CN⁻.
- 2 The relative lack of steric hindrance in the reactant results in this outcome.
- 3 The reaction proceeds largely via the $S_N 2$ mechanism.



- 23 In which sequence are the compounds listed in order of increasing ease of hydrolysis?
 - **A** C_6H_5Cl , CH_3CH_2Cl , CH_3COCl
 - **B** CH_3CH_2I , CH_3CH_2Br , CH_3CH_2Cl
 - **C** C_6H_5Cl , CH_3COCl , CH_3CH_2Cl
 - **D** CH_3COCl , CH_3CH_2Cl , CH_3CH_2Br

Topic: Halogen Derivatives – reactivity of C–X bond

Order of reactivity towards **nucleophilic substitution**: $C_6H_5Cl < R-Cl < RCOCl$

For acyl chloride:

- The carbonyl C atom is bonded to two electronegative atoms O and Cl
- This makes the carbonyl C atom highly electron-deficient
- Hence, the *highly electron deficient carbonyl C atom* is **very susceptible to nucleophilic substitution which occurs readily.**
- For chloroalkane:
- There is only one electronegative chlorine atom bonded to the alkyl C atom
- Hence, the alkyl C atom is less electron deficient.
- Less susceptible to nucleophilic substitution compared to the acyl chloride For chloroarene:
- The lone pair of electrons on the chlorine atom is delocalised into the benzene ring.
- This strengthens the carbon-halogen (C-X) bond in halogenoarenes due to presence of partial double bond character.

Order of reactivity towards **nucleophilic substitution**: R-Cl < R-Br < R-I

- Nucleophilic substitution involves the breaking of the C–X bond hence the relative reactivity depends of the C–X bond strength
- Bond energy : C–I < C–Br < C–C/
- Bond length : C–I > C–Br > C–C/
- Bond strength : C–I < C–Br < C–C/

Answer: A - similar to 2022/P3/Q1

24 Carvone is a compound that has two enantiomers with very different odour. One enantiomer has a sweetish mint smell, while the other has a spicy aroma.

Which statements correctly describe properties of a pair of enantiomers?

- 1 They have identical chemical properties except interaction with another chiral molecule.
- **2** They have the same structural formula but are non-superimposable mirror images of each other.
- 3 They rotate plane-polarised light to the same extent but in opposite directions.
- **4** They have different boiling points and solubility.

A 1, 2 and 3	B 2 and 3	C 1, 2 and 4	D 1, 2, 3 and 4	
Topic: Introduction	to Organic Ch	emistry - enantiomerisn	n	
A pair of enantiomers images of each other As per syllabus learn properties in only on They also have ident molecule	s are with at leas r. ning outcomes (e rotation of plane tical chemical pr	et one chiral carbon, resu e) and (f) below, the resul e-polarised lights (hence operties except in their in	Iting in non-superimposa tant differences in physic 3 is correct but 4 is incorr teractions with another c	ble I al I ect). I hiral I
(e) recognise that an o molecules	ptically active san	nple rotates plane-polarised	light and contains chiral	I I I
rotate plane-polarised	light	lical physical properties exc		I uley
(g) recognise that enar another chiral molecule	ntiomers have ider e	ntical chemical properties e	cept in their interactions wi	th I I
Answer: A – similar	to 2022/P1/Q18	which was challenging f	or candidates.	ا ا

25 Propanal can react via a three–stage process to give 2–bromopropane.



Which reagents could be used for the three stages?

	first stage	second stage	third stage		
Α	NaBH ₄	HBr(conc)/heat	H ₂ SO ₄ (conc)/heat		
B	<mark>NaBH₄</mark>	H ₂ SO ₄ (conc)/heat	HBr(g)		
С	H ₂ SO ₄ (conc)/heat	NaBH ₄	HBr(g)		
D	H ₂ with nickel	H₂SO₄(aq)/heat	HBr(g)		



26 *K*_a values of three acids are given.

acid	Ka		
CH₃CO₂H	1.74 x 10 ^{–5}		
CH ₂ FCO ₂ H	2.63 x 10 ⁻³		
CH ₃ CH ₂ CO ₂ H	1.32 x 10⁻⁵		

Which statement is correct?

- **A** The K_a of HCO₂H is smaller than 1.74 x 10⁻⁵.
- **B** The K_a of CF₃CO₂H is smaller than 2.63 x 10⁻³.
- **C** In two separate solutions of CH₃CO₂H and CH₂FCO₂H which have the same concentration, the pH of CH₂FCO₂H should be greater.
- D In two separate solutions of CH₂FCO₂H and CH₂BrCO₂H which have the same pH, there is a higher concentration of CH₂BrCO₂H.

Topic: Carboxylic Acids Compounds – acidity strength The weaker the acid, the less it dissociates, the lower the value of K_a

A. Comparing CH₃CO₂H and HCO₂H, the electron donating CH₃ group intensifies the negative charge on the oxygen atom of the conjugate base of CH₃CO₂H, making it less stable and more likely to accept H₊. CH₃CO₂H is a weaker acid than HCO₂H. The K_a of HCO₂H is larger than the K_a of CH₃CO₂H. This statement is wrong.

B The electron withdrawing F atom disperses the negative charge on the oxygen atom of the conjugate base of CF₃CO₂H, making it more stable and less likely to accept H⁺. CF₃CO₂H will be a stronger acid than CH₂FCO₂H, as there are three electron-withdrawing F atoms. The K_a of CF₃CO₂H is expected to be larger than the K_a of CH₂FCO₂H. The statement is wrong.

C K_a of CH₂FCO₂H is higher than the K_a of CH₃CO₂H, hence CH₂FCO₂H will dissociate to a larger extent to produce a higher [H⁺] given same concentration of the acids, leading to a lower pH. The statement is wrong.

D The Br is less electronegative than F, hence will disperses the negative charge on the oxygen atom of the conjugate base of CH_2BrCO_2H to a smaller extent, making it less stable than conjugate base of CH_2FCO_2H . CH_2BrCO_2H will be a weaker acid than CH_2FCO_2H , dissociating to a smaller extent to produce H^+ .

In two separate solutions of CH_2FCO_2H and CH_2BrCO_2H , if the pH of the solutions is the same, it means the [H⁺] is the same. Since CH_2BrCO_2H dissociates to smaller extent, this implies that the position of equilibrium lies more to the left relative to CH_2FCO_2H . This shows that the concentration of CH_2BrCO_2H is higher than CH_2FCO_2H at equilibrium.

L

Answer: D – similar to 2022/P1/Q26 which was challenging for candidates.

27 The pK_a values of the C₁ carboxyl group, C₂ carboxyl group, and amino group of aspartic acid are 1.88, 3.65, and 9.60, respectively. The structure of aspartic acid is as shown below:



Which is the predominant form of aspartic acid at pH 7?



28 The reaction between ethanal and HCN is given below:



Which one of the following statements about this reaction is not true?

- A The reaction is bimolecular.
- **B** The organic product mixture formed is optically active.
- **C** The rate of reaction can be increased by a small amount of base.
- **D** The intermediate formed in the rate-determining step is tetrahedral in shape.

Topic: Carbonyl Compounds – describe the mechanism of the nucleophilic addition reactions of hydrogen cyanide with aldehydes

Step 1 is slow step, also known as the rate-determining step. 2 species are involved in the slow step forming an alkoxide ion intermediate. The carbonyl carbon rehybridises from sp² to sp³. sp³ carbon has tetrahedral in shape. Hence, Option A and D are correct.

Option B is not true because the carbonyl carbon is sp^2 hybridised, it is trigonal planar. Thus, the nucleophile (CN⁻) can attack from above or below the plane about the carbonyl carbon in Step 1 with equal probability. Both enantiomeric intermediates are formed in equal amounts, resulting in a racemic mixture. Hence, the product mixture formed is optically inactive.

Option C is correct. HCN is a weak acid and dissociates only partially in water.

 $HCN + H_2O \rightleftharpoons H_3O^+ + CN^-$

Thus it is a poor source of the nucleophile, CN–. A small amount of sodium hydroxide is used to increase the cyanide concentration and speed up the reaction.

 $\text{HCN} + \text{NaOH} \rightarrow \text{H}_2\text{O} + \text{NaCN}$

Answer: B

I

29 Two electrode potentials are given.

$Cr^{3+} + e^{-} \Longrightarrow Cr^{2+}$	<i>E</i> [⊕] = −0.41 V
$F_2 + 2e^- \Longrightarrow 2F^-$	<i>E</i> [⊕] = +2.87 V

Which species is the strongest reducing agent?

A		F⁻	В	F ₂	С	Cr ²⁺	D	Cr ³⁺			
	Topic: Conce	Electrochemis ot: Using <i>E</i> ^o to	stry o deter	mine strength	of oxic	lising power.					
	A reducing agent reduces others and it gets oxidised (donates electrons). The only 2 species undergoing oxidation are Cr^{2+} and F^- . For the species ions to donate electrons, it must be more readily oxidised, i.e. less positive E^{0} value in the data booklet. Thus the only possible answer is C.										
	Answe	r: C						, , , ,			

30 Cu^{2+} ion forms a blue octahedral complex with a ligand **L**. Ligand **L** is a neutral molecule that has no ionic charge. Various samples containing different volumes of 1×10^{-5} mol dm⁻³ Cu²⁺ and 3×10^{-5} mol dm⁻³ ligand **L** were prepared.

The following graph was obtained when the colour intensity of the samples was measured using a colorimeter.



Which statement about the complex ion is correct?

- A Ligand L is a bidentate ligand.
- **B** The complex ion absorbs blue light.
- **C** The overall charge of the complex ion is 4–.
- **D** The coordination number of the Cu^{2+} ion is 3.

Topic: Transition Metals

Mole ratio of Cu²⁺ and Ligand L is 1:3 (1×10^{-7} mol : 3×10^{-7} mol)

1 mole of Cu^{2+} combined with 3 mole of Ligand L to form complex ion. Since there are 3 ligands and the coordination no. of Cu^{2+} is 6 as it forms octahedral complex, Ligand L is therefore a bidentate ligand.

Since Ligand L molecule is uncharged, hence, the overall charge of the complex ion has the same charge as Cu^{2+} .

The colour observed is the complementary colour of the wavelength of light absorbed. Since the colour of complex ion is blue, the wavelength of light absorbed is orange.

Answer: A