

# CATHOLIC JUNIOR COLLEGE JC2 PRELIMINARY EXAMINATIONS Higher 2

# CHEMISTRY Paper 1 Multiple Choice

# 9647/01 Wednesday 3 September 2014 1 hour

Additional Materials: Multiple Choice Answer Sheet Data Booklet

# **READ THESE INSTRUCTIONS FIRST**

Write your name and HT group on the Answer Sheet in the spaces provided. Write in soft pencil. Do not use staples, paper clips, highlighters, glue or correction fluid.

There are **forty** 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

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**

# Section A

For each question there are *four* possible answers, *A*, *B*, *C* and *D*. Choose the one you consider to be *correct* and record your choice in soft pencil on the *separate Answer Sheet* provided.

1 Use of the Data Booklet is relevant to this question.

Which one of the following has the same number of the stated particle as atoms in 127 g of iodine at room conditions?

A number of atoms in 79 g of gold

B number of anions in 0.5 mol of barium chloride

- **C** number of ions in 1 mol of potassium bromide
- D number of molecules in 10 g of hydrogen fluoride

#### **Answer: B**

127 g of I<sub>2</sub> =  $\frac{127}{127 \times 2}$  mol = 0.5 mol of I<sub>2</sub> molecules = 1.0 mol of I atoms

 $= 6.02 \times 10^{23}$  I atoms

- **A**: 79 g of Au =  $\frac{79}{197}$  mol of Au atoms
  - = 0.401 mol of Au atoms
  - $= 2.41 \times 10^{23}$  Au atoms
- **B**: Since there are 2 C*l*<sup>-</sup> anions in 1 BaC*l*<sub>2</sub>, there is 1 mol of C*l*<sup>-</sup> in 0.5 mol BaC*l*<sub>2</sub> And thus the no. of anions present =  $6.02 \times 10^{23}$  C*l*<sup>-</sup>
- **C**: Since there are 2 ions in 1 KBr, there are 2 mol of ions (K<sup>+</sup> and Br<sup>-</sup>) in 1 mol KBr And thus the no. of ions present =  $1.20 \times 10^{24}$  ions
- **D**: 10 g of HF =  $\frac{10}{1+19}$  mol of HF molecule
  - = 0.500 mol of HF molecule
  - =  $3.01 \times 10^{23}$  HF molecule

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

In polluted air, the white paint pigment in older oil paintings forms lead(II) sulfide, PbS, that is black in colour. To restore the white colour, an oxidising agent, hydrogen peroxide,  $H_2O_2$ , is used.

Given that 0.239 g of PbS requires 25 cm<sup>3</sup> of 0.160 mol dm<sup>-3</sup> H<sub>2</sub>O<sub>2</sub> for oxidation, what is the possible identity of the white paint pigment?

A S<sub>8</sub> B PbS<sub>2</sub> C PbSO<sub>3</sub> D PbSO<sub>4</sub> Answer: D no. of mol of PbS =  $\frac{0.239}{207 + 32.1}$  = 0.00100 mol no of mol of H<sub>2</sub>O<sub>2</sub> =  $\frac{25}{1000}$  × 0.160 = 0.00400 mol Thus 4 H<sub>2</sub>O<sub>2</sub> = PbS From data booklet, H<sub>2</sub>O<sub>2</sub> + 2H<sup>+</sup> + 2e<sup>-</sup>  $\rightarrow$  2H<sub>2</sub>O Thus, 4 H<sub>2</sub>O<sub>2</sub> = 8 e<sup>-</sup>  $\Rightarrow$  PbS = 8 e<sup>-</sup> Thus S<sup>2-</sup> loses 8 e<sup>-</sup>. S in PbS is oxidised from -2 to +6. Thus a possible identity is PbSO<sub>4</sub>.

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

Which one of the following species has more neutrons than electrons and more electrons than protons?

<b>Α</b> <sup>37</sup> CΓ	<b>B</b> <sup>48</sup>	Ti <sup>4+</sup>	C <sup>79</sup> Br <sup>+</sup>	<b>D</b> ${}^{32}S^{2-}$
Answer: A				
	<sup>37</sup> C <i>l</i> <sup>-</sup>	<sup>48</sup> Ti <sup>4+</sup>	<sup>79</sup> Br <sup>+</sup>	<sup>32</sup> S <sup>2-</sup>
Proton:	17	22	35	16
Electron:	18	18	34	18
Neutron:	20	26	44	16

4 In recent years, many scientists have been researching the potential of copper complexes as drugs in chemotherapy due to their ability to inhibit cell proliferation and induce apoptosis in cells. An example of such a complex is shown below:



Which one of the following best describes the bonds formed with Cu?

	Cu-N <sup>1</sup>	Cu-N <sup>2</sup>
Α	dative	π
В	Π	ionic
C	ionic	dative
D	σ	π

# Answer: C

 $N^1$  is negatively charged. It can participate in ionic bonding with  $Cu^{2+}$  ion.

 $N^2$  has a lone pair of electrons. Thus it can only form dative covalent bond with  $Cu^{2+}$  ion as it is electrically neutral.

5 What is the most likely bond angle of the sulfur atom in S,S-diphenylsulfilimine?



# **Answer: B**

Α

There are 3 bond pairs and 1 lone pair around central atom S. Thus the shape is trigonal pyramidal, 107°.

6 Which graph correctly describes the behaviour of fixed masses of the ideal gases I and J, where I has a higher Mr than J?





**7** Fe<sup>3+</sup> and SCN<sup>-</sup> react in a closed system to give the complex, [Fe(SCN)]<sup>2+</sup>, which is blood-red in colour.

 $Fe^{3+}(aq) + SCN(aq) \rightleftharpoons [Fe(SCN)]^{2+}(aq) \qquad \Delta H < 0$ 

Which one of the following changes will result in the solution turning pale red?

- A Increase the concentration of SCN<sup>-</sup>.
- **B** Decrease the pressure of the system.
- **C** Decrease the temperature of the system.
- D Add a small amount of dilute NaOH(aq) to the resulting mixture.

6

# Answer: D

For the solution to turn pale red, there must be a decrease in the concentration of  $[Fe(SCN)]^{2+}(aq)$ .

- A Increasing the concentration of SCN<sup>-</sup> will shift the position of equilibrium to the right, causing more [Fe(SCN)]<sup>2+</sup>(aq) to be formed.
- **B** Decreasing the pressure of the system will have no effect on the position of the equilibrium, as pressure changes only affect gases.
- **C** As the forward reaction is exothermic, decreasing the temperature of the system will cause the position of equilibrium to shift to the right.
- **D** Adding a small amount of NaOH(aq) will cause precipitation of Fe(OH)<sub>3</sub>, thus decreasing [Fe<sup>3+</sup>], resulting in the shift of position of equilibrium to the left.
- 8 Solid NaCl dissolves in water to give Na<sup>+</sup>(aq) and Cl<sup>-</sup>(aq) ions under standard conditions of 298 K, 1 atm.

$$NaCl(s) \rightarrow Na^{+}(aq) + Cl^{-}(aq)$$

$Na^{+}(g) + Cl^{-}(g) \rightarrow NaCl^{-}(s)$	$\Delta H_{\text{latt}}^{\Phi} = -781 \text{ kJ mol}^{-1}$
$Na^{+}(g) \rightarrow Na^{+}(aq)$	$\Delta H_{hyd}^{e} = -390 \text{ kJ mol}^{-1}$
$C\Gamma(g) \rightarrow C\Gamma(aq)$	$\Delta H_{hyd}^{e} = -381 \text{ kJ mol}^{-1}$

What is the standard enthalpy change of solution,  $\Delta H_{sol}^{\theta}$ , for the above reaction?

**A** -10 kJ mol<sup>-1</sup> **B** +10 kJ mol<sup>-1</sup> **C** -20 kJ mol<sup>-1</sup> **D** +20 kJ mol<sup>-1</sup>

Answer: B



 $\Delta H_{sol}^{\Theta} = -\Delta H_{latt}^{\Theta} + \Sigma \Delta H_{hyd}^{\Theta}$ = - (-781) + [(-390) + (-381)] = + 781 - 771 = +10 kJ mol<sup>-1</sup> **9** What is the pH of the resulting solution when 2.50 g of  $NH_4Cl$  is dissolved in 250 cm<sup>3</sup> of 0.100 mol dm<sup>-3</sup>  $NH_3(aq)$ ? [K<sub>b</sub> of  $NH_3 = 1.8 \times 10^{-5}$  mol dm<sup>-3</sup>]

Α	5.01	B	<mark>8.99</mark>	С	9.53	D	14.0
Ans	wer: B						
<i>M</i> <sub>r</sub> c	of $NH_4Cl = 14 + 4$	l(1) +	35.5 = 53.5				
[salt	$[] = \frac{2.50}{53.5} \times \frac{1000}{250}$	= 0.1	87 mol dm <sup>-3</sup>				
[bas	$se] = [NH_3] = 0.10$	00 mo	l dm⁻³				
рOŀ	$H = pK_b + lg\left(\frac{[sa]}{[bas]}\right)$	$\frac{lt]}{se]}$					
	= –lg(1.8 × 10 <sup>−</sup>	<sup>5</sup> ) + lg	$\left(\frac{0.187}{0.100}\right)$				
	= 4.74 + 0.27						
	= 5.01						
pH =	= 14 – pOH						
:	= 14 – 5.01						
:	= 8.99						

- **10** Equal volumes of aqueous KI and 0.200 mol dm<sup>-3</sup> of Pb(NO<sub>3</sub>)<sub>2</sub> are mixed together to precipitate PbI<sub>2</sub>. Given that the  $K_{sp}$  value of PbI<sub>2</sub> is 8.70 × 10<sup>-9</sup> mol<sup>3</sup> dm<sup>-9</sup>, which one of the following could have been the initial concentration of KI?
  - **A**  $8.70 \times 10^{-8} \text{ mol dm}^{-3}$
  - **B** 2.95 ×  $10^{-4}$  mol dm<sup>-3</sup>
  - **C** 5.90 ×  $10^{-4}$  mol dm<sup>-3</sup>
  - D 1.50 x 10<sup>-2</sup> mol dm<sup>-3</sup>

# Answer: D

 $2 \text{ I}^{-}(aq) + \text{Pb}^{2+}(aq) \rightarrow \text{PbI}_{2}(s)$ 

For precipitation of PbI<sub>2</sub> to occur, ionic product  $[Pb^{2+}][I]^2$  must be greater than the K<sub>sp</sub> value of PbI<sub>2</sub>.  $\Rightarrow$   $[Pb^{2+}][I]^2 > K_{sp}$ 

Let x be [I<sup>-</sup>]<sub>initial</sub>

$$\frac{0.200}{2} \times \left(\frac{x}{2}\right)^2 > 8.70 \times 10^{-9}$$

 $[I^{-}]_{initial} > 5.90 \times 10^{-4} \text{ mol dm}^{-3}$ 

Option D is the only one that has a value higher than  $5.90 \times 10^{-4}$  mol dm<sup>-3</sup>

**11** Two electrode potentials are given below:

$Co^{3+} + e^{-} \rightleftharpoons Co^{2+}$	E <sup>e</sup> = +1.82 V
$Sn^{4+} + 2e^{-} \rightleftharpoons Sn^{2+}$	E <sup>e</sup> = +0.15 V

Which species is the strongest reducing agent?

Α	Co <sup>2+</sup>	В	Co <sup>3+</sup>	C	Sn <sup>2+</sup>	D	Sn⁴
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# Answer: C

Reducing agents are oxidised during a redox reaction. As  $E_{Sn^{4+}/Sn^{2+}}^{\theta}$  is less positive than  $E_{Co^{3+}/Co^{2+}}^{\theta}$ , Sn<sup>2+</sup> has a higher tendency to be oxidised. Thus, Sn<sup>2+</sup> is the strongest reducing agent.

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

The cell shown in the diagram is set up under standard conditions where X and Y are platinum electrodes.



Which one of the following statements is correct?

- **A** Addition of AgNO<sub>3</sub>(aq) to half-cell **A** will not affect  $E_{cell}^{e}$ .
- **B** The voltmeter will show a reading of about +1.52 V.
- **C** The electrons will flow from **X** to **Y** through the voltmeter.
- **D Y** will be the negative electrode.

#### **Answer: C**

 $Cl_2 + 2e^- \rightleftharpoons 2Cl^- \qquad E^{\theta} = +1.36 \text{ V}$  $MnO_4^- + 8H^+ + 5e^- \rightleftharpoons Mn^{2+} + 2H_2O \qquad E^{\theta} = +1.52 \text{ V}$ 

- A When AgNO<sub>3</sub>(aq) is added to half-cell **A**, Cl is precipitated in the form of AgC*l*(s). Thus, [C*l*] decreases, the position of equilibrium of  $Cl_2 + 2e^- \rightleftharpoons 2Cl^-$  shifts to the right.  $E_{Cl_2/Cl^-}$  becomes more positive and thus  $E_{cell}$  becomes less positive.
- **B** Oxidation occurs in half-cell **A**, while reduction occurs in half-cell **B**.  $E_{cell}^{\circ} = +1.52 - (+1.36) = +0.16 \text{ V}$
- **C** As oxidation occurs in half-cell **A**, electrons are released from **X** (anode). These electrons travel towards **Y** (cathode) via the wire in the external circuit.
- **D** As **X** gives out electrons, it is the negative electrode. Since **Y** receives electrons from the external circuit, it must be the positive electrode.
- **13** Hydrogen peroxide reacts with iodide ions in acidic solution as follows:

$$H_2O_2(aq) + 2 H^+(aq) + 2 I(aq) \rightarrow 2 H_2O(l) + I_2(aq)$$

The rate equation was found experimentally to be: rate =  $k[H_2O_2][I^{-}]$ .

Which mechanism is consistent with the kinetics of this reaction?

Α	$\mathrm{H_2O_2} + \mathrm{H^+} \rightarrow \mathrm{H_2O} + \mathrm{OH^+}$	(fast)	В	$2 \text{ H}^{+} + 2 \text{ I}^{-} \rightarrow 2 \text{ HI}$	(fast)
	$H^+ + OH^+ + 2 I^- \rightarrow H_2O + I_2$	<sub>2</sub> (slow)		$2 \text{ HI} + \text{H}_2\text{O}_2 \rightarrow \text{I}_2 + 2 \text{ H}_2\text{O}$	(slow)

C	H <sub>2</sub> O <sub>2</sub> + I <sup>−</sup> → H <sub>2</sub> O + IO <sup>−</sup>	(slow)	D	$H_2O_2 + I^- + H^+ \rightarrow H_2O + HIO$	(fast)
	H⁺ + IO <sup>−</sup> → HIO	(fast)		$HIO + \mathrm{I}^{\scriptscriptstyle -} \to \mathrm{I}_2 + \mathrm{OH}^{\scriptscriptstyle -}$	(slow)
	$HIO + H^{+} + I^{-} \to I_2 + H_2O$	(fast)		$OH^- + H^+ \to H_2O$	(fast)

# Answer: C

The rate equation shows that in the slow step, only one molecule of  $H_2O_2$  and one molecule of  $\Gamma$  are involved. H<sup>+</sup> is not involved in the slow step at all.

**14** The diagram shows the Boltzmann distribution of molecular energies of a gas at a given temperature.



Which one of the following statements correctly describes what happens as temperature increases?

- A The activation energy of the reaction is lowered.
- **B** The maximum of the curve is displaced to the left.
- **C** The proportion of molecules with  $E < E_{max}$  increases.
- D The proportion of molecules with energies above any given value increases.

#### Answer: D

- A Raising or lowering temperature has no effect on the activation energy.
- B The maximum of the curve is displaced to the right as temperature increases.
- C The proportion of molecules with  $E < E_{max}$  decreases as the peak is shifted to the right as temperature increases.
- D As temperature increases, the average kinetic energy of the molecules increases and more molecules acquire higher kinetic energies.

**15** For the oxides of Period 3 elements (Na to P), which property decreases from Na<sub>2</sub>O to  $P_4O_{10}$ ?

- A covalent character
- B melting point
- C pH when mixed with water
- **D** solubility in aqueous alkali

Answer: C

Oxic	de	Na <sub>2</sub> O	MgO	$Al_2O_3$	SiO <sub>2</sub>	$P_4O_6$ and $P_4O_{10}$
form	ula					
Struct	ture		Giant ionic		Giant covalent	Simple covalent (molecular)
Melti	ng	1280	2900	2040	1610	24
Point	/ °C					580
Acid/b	ase	Basic:	Basic:	Amphoteric:	Acidic: forms	Acidic
behav	iour	Na₂O + 2H <sup>+</sup> → 2Na <sup>+</sup> + H₂O	MgO + 2H <sup>+</sup> → Mg <sup>2+</sup> + H <sub>2</sub> O	$AI_{2}O_{3} + 6H^{+} \rightarrow 2Al^{3+} + 3H_{2}O$ $AI_{2}O_{3} + 2OH^{-} + 3H_{2}O \rightarrow 2Al(OH)_{4}^{-}$	$SiO_3^{2^{-}}$ with base $SiO_2 + 2NaOH$ $\rightarrow Na_2SiO_3 + H_2O$ $SiO_2 + CaO \rightarrow CaSiO_3$	$P_4O_6 + 8NaOH$ $\rightarrow 4Na_2HPO_3 + 2H_2O$ $P_4O_{10} + 12NaOH$ $\rightarrow 4Na_3PO_4 + 6H_2O$
Rxn w/H₂O	Eqn	Na <sub>2</sub> O + H <sub>2</sub> O → 2NaOH	MgO + H₂O ≓ Mg(OH)₂ (slightly alkaline as only mildly soluble)	Giant ionic with high lattice energy. Will not dissolve in water.	Giant covalent. Will not dissolve.	$P_4O_6 + 6H_2O \rightarrow$ $4H_3PO_3$ $P_4O_{10} + 6H_2O \rightarrow$ $4H_3PO_4$
	рН	13	9	7 (the pH of water)	7 (the pH of water)	2

- 16 Which property of strontium, a Group II element, and its compounds is correct?
  - A Strontium does not burn in air.
  - **B** Strontium does not react with steam.
  - **C** Strontium hydroxide produces strontium oxide when heated strongly.
  - **D** Strontium nitrate decomposes at a lower temperature than calcium nitrate.

# Answer: C

- A Strontium burns in air to form strontium oxide.
- **B** Strontium reacts with both cold water and steam to form the hydroxide.
- **C**  $Sr(OH)_2 \longrightarrow SrO + H_2O$
- **D** Strontium nitrate decomposes at a higher temperature because of the lower charge density of  $Sr^{2+}$  hence leading to less polarisation of the  $NO_3^-$  ion.

- **17** Which one of the following statements is most likely to be true for astatine, the element below iodine in Group VII of the Periodic Table?
  - A Potassium astatide and hot dilute sulfuric acid react to form white fumes of hydrogen astatide.
  - **B** Astatine and aqueous potassium chloride react to form aqueous potassium astatide and chlorine.
  - C Sodium astatide and hot concentrated sulfuric acid react to form astatine.
  - **D** Silver astatide and dilute aqueous ammonia react to form a solution of a soluble complex.

# Answer: C

- A No reaction! Reacts only with concentrated sulfuric acid!
- **B** No reaction! At<sub>2</sub> is a weaker oxidising agent than  $Cl_2$  so the former cannot oxidise  $Cl^r$  to  $Cl_2$ .
- **C** NaAt reacts with conc sulfuric acid to give HAt which is then further oxidised by conc sulfuric acid to At<sub>2</sub> (Similar reactions to that of NaI).
- **D** AgAt is insoluble in  $NH_3(aq)$ .
- **18** The hexa-aquairon(III) ion hydrolyses as shown below.

$$[Fe(H_2O)_6]^{3+}(aq) + H_2O(l) \rightleftharpoons [Fe(H_2O)_5OH]^{2+}(aq) + H_3O^{+}(aq)$$

Which one of the following statements is correct?

- A The hydrolysis is favoured by low pH.
- **B** An aqueous solution of  $FeCl_3$  is alkaline.
- **C** The iron undergoes a change in oxidation state from +3 to +2.
- D The corresponding hexa-aquairon(II) ion, [Fe(H<sub>2</sub>O)<sub>6</sub>]<sup>2+</sup>(aq) is relatively less likely to undergo hydrolysis.

## **Answer: D**

- A At low pH (H<sub>3</sub>O<sup>+</sup> present), position of equilibrium shifts to left, so hydrolysis in <u>NOT</u> favoured!
- **B** No, as clearly it is acidic due to the presence of  $H_3O^+(aq)$ .
- **C** No change in O.S., +3 before and after.
- **D** Yes, as the charge density of  $Fe^{2+}$  is relatively low and so is less likely to polarise  $H_2O$  (i.e. less likely to undergo hydrolysis).

- 19 Which one of the following is an optically active compound and is soluble in water?
  - **A**  $CH_3CH=CHCO_2H$
  - B CH<sub>3</sub>CH=C(CH<sub>3</sub>)<sub>2</sub>
  - C CH<sub>3</sub>CH<sub>2</sub>CHBrCH<sub>3</sub>
  - D CH<sub>3</sub>CH(OH)CO<sub>2</sub>H

# Answer: D

Both **A** and **B** are non-chiral and therefore are not optically active.

C is chiral and therefore is optically active but is insoluble in water.

**D** has a chiral carbon centre and so is optically active. It is also soluble due the Hbonding with water as a result of the –OH group present in both the alcohol and carboxylic acid.

20 γ-Terpinene is a naturally-occurring hydrocarbon and has been isolated from a variety of plant sources.

On treatment of  $\gamma$ -terpinene with an excess of hot concentrated manganate(VII) ions, two organic products are formed. It was found that compound **X** evolves CO<sub>2</sub> with Na<sub>2</sub>CO<sub>3</sub>, gives an orange precipitate with 2,4-dinitrophenylhydrazine and a yellow precipitate with alkaline aqueous iodine.



Which one of the following shows a possible structure for  $\gamma$ -terpinene?





**A**: contains a terminal alkene and thus CO<sub>2</sub> and only 1 organic product would be formed upon oxidative cleavage.

**B**: gives propanone as one of the products instead and is thus not possible.

**D**: Ethanedioic acid would be obtained which undergoes further oxidation to give  $CO_2$  and  $H_2O$ . Hence only 1 organic product obtained for **D** as well.

Compound **X** contains a carboxylic acid group and a ketone that contains  $-COCH_3$  group.

Option **C** is thus the correct option.



**21** The following reaction scheme outlines the production of one of the monomers of nylon-6,6, hexane-1,6-diamine, from 1,4-dibromobutane.

BrCH<sub>2</sub>CH<sub>2</sub>CH<sub>2</sub>CH<sub>2</sub>Br  $\xrightarrow{\text{Step I}}$  NCCH<sub>2</sub>CH<sub>2</sub>CH<sub>2</sub>CH<sub>2</sub>CH<sub>2</sub>CN  $\xrightarrow{\text{Step II}}$  H<sub>2</sub>N(CH<sub>2</sub>)<sub>6</sub>NH<sub>2</sub> 1,4-dibromobutane hexane-1,6-diamine

Which one of the following shows the reagents and conditions for each step?

	Step I	Step II
Α	alcoholic $NH_3$ , heat	aqueous KOH, room temperature
В	alcoholic KCN, heat	aqueous NaOH, heat
С	HCN, with trace amount of KCN, 10-20 °C	LiA/H₄ in dry ether
D	alcoholic KCN, heat	H <sub>2</sub> , Ni catalyst, heat

## **Answer: D**

There is an increase in number of C atoms by 2. Thus step-up reaction is involved.

Step I involves heating halogenoalkanes with KCN(alc) or NaCN(alc). Step II involves the reduction of nitriles (using H<sub>2</sub>, Ni catalyst or LiA*l*H<sub>4</sub> in dry ether) to form the amine.

22 Rosmarinic acid occurs in culinary herbs such as rosemary, sage and thyme.



Which one of the following statements about rosmarinic acid is true?

- A 1 mole of rosmarinic acid reacts with 6 moles of hot aqueous NaOH.
- **B** Rosmarinic acid gives an orange precipitate with 2,4-dinitrophenylhydrazine.
- **C** When rosmarinic acid is heated with ethanoic acid and concentrated H<sub>2</sub>SO<sub>4</sub>, an ester is formed.
- **D** When reacted with LiA*l*H<sub>4</sub>, each molecule of rosmarinic acid would incorporate 4 hydrogen atoms.

# **Answer: A**

- A Rosmarinic acid can undergo (1) acid-base reaction with NaOH (due to the acidic phenol and carboxylic acid groups and (2) alkaline hydrolysis (due to the ester group). Thus, 1 mol of rosmarinic acid reacts with 6 mol of hot aq NaOH
- **B** Rosmarinic acid does not contain any carbonyl groups (aldehydes or ketones). Esters do NOT give a positive test with 2,4-dinitrophenylhydrazine.
- **C** Phenyl esters can only be formed by reacting acyl halides with phenols. Note that phenols are very weak nucleophiles.
- **D** Both the carboxylic acid and ester will undergo reduction with LiA/H<sub>4</sub>. Note that the ester will undergo reduction with LiA/H<sub>4</sub> to form two alcohols. The C=C bond can only undergo reduction with H<sub>2</sub>, Ni catalyst.

**23** The nitrogen present in compounds can react in various ways. In which one of the following reactions is nitrogen acting as a nucleophile?



# **Answer: D**

- A Nitrobenzene undergoes reduction and is an oxidising agent here.
- **B** Hydrolysis of the amide occurs. N is not acting as the nucleophile here. Recall that the lone pair of electrons on N can be delocalised over the C=O.
- **C** Acid-base reaction, NH<sub>3</sub> acts as the base
- **D** NH<sub>3</sub> is acting as the nucleophile here. The acyl chloride undergoes nucleophilic substitution to give the amides.
- 24 Which one of the following statements is true about  $S_N1$  and  $S_N2$  mechanisms?
  - **A**  $S_N 1$  is a one-step reaction.
  - $\mathbf{B}$  S<sub>N</sub>1 will cause an inversion in the configuration.
  - C S<sub>N</sub>2 results in the formation of a carbocation intermediate.
  - **D**  $S_N 2$  is more likely to occur for  $CH_3CH_2CH_2CH_2Cl$  as compared to  $CH_3C(Cl)(CH_3)_2$ .

#### **Answer: D**

- $A = S_N 1$  is a multi-step reaction.
- **B**  $S_N 1$  will not cause an inversion in the configuration, only  $S_N 2$  will cause an inversion in the configuration.
- C S<sub>N</sub>2 results in the formation of an unstable transition state.
- D S<sub>N</sub>2 is more likely to occur for CH<sub>3</sub>CH<sub>2</sub>CH<sub>2</sub>CH<sub>2</sub>Cl (a primary halogenoalkane) as compared to CH<sub>3</sub>C(Cl)(CH<sub>3</sub>)<sub>2</sub> (a tertiary halogenoalkane).
- 25 Phenylpropanone is used in the manufacture of methamphetamine and amphetamine.A molecule of phenylpropanone is shown below:



Which one of the following is a correct observation when phenylpropanone reacts with the respective reagents?

- **A** When added to aqueous bromine, orange aqueous bromine decolorises.
- **B** When heated with aqueous alkaline iodine, no yellow precipitate is formed.

**C** When heated with acidified KMnO<sub>4</sub>, purple KMnO<sub>4</sub> decolorises.

**D** When heated with Tollens' reagent, a silver mirror is formed.

# Answer: C

There are 2 functional groups present in phenylpropanone, namely benzene ring and ketone.

- A Phenylpropanone does not react with aqueous bromine, therefore it does not cause aqueous bromine to decolourise.
- **B** Heating with aqueous alkaline iodine will be able to form a yellow precipitate of CHI<sub>3</sub> due to the presence of methyl carbonyl carbon (CH<sub>3</sub>CO).
- **C** Phenylpropanone is able to be undergo side-chain oxidation with hot acidified KMnO<sub>4</sub>, thus it is able to decolourise purple KMnO<sub>4</sub>.
- **D** As a ketone, phenylpropanone is not able to produce a silver mirror with Tollens' reagent.

26 Which pair of the following reactions would produce the same intermediate?

- I  $CH_3CH(OH)CH_3 \rightarrow intermediate \rightarrow CH_3C(OH)CNCH_3$
- II  $CH_3CH=CH_2 \rightarrow intermediate \rightarrow CH_3CH(CN)CH_3$
- III  $(CH_3)_2C=CH_2 \rightarrow intermediate \rightarrow CH_3CH(OH)CH_3$
- $IV \qquad CH_3CH_2CH_2OH \rightarrow intermediate \rightarrow CH_3CH_2CH(OH)CN$
- A I and II B I and III C II and IV D III and IV

# **Answer: B**

- I  $CH_3CH(OH)CH_3 \rightarrow \underline{CH_3COCH_3} \rightarrow CH_3C(OH)CNCH_3$
- II  $CH_3CH=CH_2 \rightarrow \underline{CH_3CH(Cl)CH_3} \rightarrow CH_3CH(CN)CH_3$
- III  $(CH_3)_2C=CH_2 \rightarrow \underline{CH_3COCH_3} \rightarrow CH_3CH(OH)CH_3$
- IV  $CH_3CH_2CH_2OH \rightarrow \underline{CH_3CH_2CHO} \rightarrow CH_3CH_2CH(OH)CN$
- **27** Which one of the following statements best explains why CH<sub>3</sub>CH<sub>2</sub>COC*l* readily hydrolyses in water but CH<sub>3</sub>CH<sub>2</sub>CO<sub>2</sub>CH<sub>3</sub> does not?
  - A The C=O bond in  $CH_3CH_2COCl$  is more polar and thus weaker than that in  $CH_3CH_2CO_2CH_3$ .
  - **B** The Cl atom in  $CH_3CH_2COCl$  is more electronegative than the O atom in the  $-OCH_3$  in  $CH_3CH_2CO_2CH_3$ .
  - **C** The carbonyl carbon in  $CH_3CH_2COCl$  has a larger partial positive charge as compared to that in  $CH_3CH_2CO_2CH_3$ .
  - **D** There are more electrons on Cl atom in  $CH_3CH_2COCl$  as compared to the O atom in the  $-OCH_3$  in  $CH_3CH_2CO_2CH_3$ .

# Answer: C

The bond that breaks during hydrolysis of  $CH_3CH_2COCl$  is C-Cl and for  $CH_3CH_2CO_2CH_3$  is the C-O bond.

- A Statement A is wrong because the C=O bond does not break during hydrolysis.
- **B** Statement B is wrong because O is more electronegative than Cl.
- **C** Statement C is correct and because of this factor, the carbonyl carbon in CH<sub>3</sub>CH<sub>2</sub>COC*l* is able to attract the nucleophile more readily as compared to that

in  $CH_3CH_2CO_2CH_3$ . Thus making  $CH_3CH_2COCl$  more readily hydrolysed in water than  $CH_3CH_2CO_2CH_3$ .

- D CI does have more electrons than O but it does not explain why CH<sub>3</sub>CH<sub>2</sub>COC*l* is more readily hydrolysed in water than CH<sub>3</sub>CH<sub>2</sub>CO<sub>2</sub>CH<sub>3.</sub>
- **28** Given that  $G \longrightarrow NH_2$  is a weaker base than phenylamine, what is the relative order of **decreasing** acidity of the three compounds shown below?



# **Answer: A**

Since  $G \longrightarrow NH_2$  is a weaker base than phenylamine, G must be an electronwithdrawing group as G will decrease the availability of lone pair of electrons on N atom to accept a proton.

Having an electron-withdrawing group in compound I will make compound I a stronger acid than benzoic acid (compound III). This is because the electron-withdrawing group in compound I will make the O-H bond in compound I more polarised as compared to that in benzoic acid (compound III), thus making it easier for the O-H bond to break in compound I.

Compound II has an electron-donating methyl group which will make compound II a weaker acid than benzoic acid (compound III). This is because the electron-donating group in compound II will make the O-H bond in compound II less polarised as compared to benzoic acid (compound III), thus making it harder for the O-H to break in compound II.

Therefore the relative order of decreasing acidity is | > | | | > | |.

**29** Partial hydrolysis of a tetrapeptide produces alanine, glycine and the following dipeptides.

Dipeptide 1: Ala-Gly Dipeptide 2: Ala-Ala Dipeptide 3: Gly-Ala

Which one of the following is not a possible identity of this tetrapeptide?

A Ala-Ala-Gly-Ala

B Ala-Ala-Ala-Gly

C Ala-Gly-Ala-Ala

D Gly-Ala-Ala-Gly

# Answer: B

From the three dipeptides above, it can be deduced that there are two different types of amino acid residues, Ala and Gly. Since amino acids sequence are read from the N-terminus to the C-terminus, the sequence of the dipeptides cannot be flipped. While options **A**, **C** and **D** are possible identities of the tetrapeptide, the Gly-Ala dipeptide 3 is not observed in option **B**, hence **B** is the answer.

- 30 Which salt will be the most acidic in aqueous solution?
  - **A**  $CH_3CH_2NH_3^+Cl$
  - **B**  $C_6H_5NH_3^+Cl^-$
  - **C** Na<sup>+</sup>C*l*<sup>−</sup>
  - **D**  $CH_3CO_2^-Na^+$

## Answer: B

For Options **A** and **B**, since basicity decreases in this order:  $CH_3CH_2NH_2 > C_6H_5NH_2$ , hence acidity of conjugate acid increases in this order:  $CH_3CH_2NH_3^+ < C_6H_5NH_3^+$ For Option **C**,  $Na^+CI^-$  is neutral in aqueous solution. For Option **D**,  $CH_3CO_2^-$  is the conjugate base of  $CH_3CO_2H$  and will give an alkaline solution in water.

# **Section B**

For each of the questions in this section, one or more of the three numbered statements **1** to **3** may be correct.

Decide whether each of the statements is or is not correct (you may find it helpful to put a tick against the statements that you consider to be correct).

The responses A to D should be selected on the basis of

Α	В	C	D
1, 2 and 3 are correct	1 and 2 only are	2 and 3 only are	1 only is correct
	correct	correct	

No other combination of statements is used as a correct response.

- **31** Which of the following statements is correct about the complete combustion of an alkene, C<sub>n</sub>H<sub>2n</sub>, in oxygen?
  - **1** The volume of oxygen required is directly proportional to the number of carbon atoms present in the molecule.
  - 2 The volume of gas produced at 25 °C is the same as for the complete combustion of an alkane,  $C_nH_{2n+2}$ .
  - 3 At 120 °C, the volume of steam produced is twice the volume of carbon dioxide.

# Answer: B

$$C_nH_{2n} + (\frac{3n}{2}) O_2 \rightarrow n CO_2 + n H_2O$$

$$C_nH_{2n+2}$$
 + ( $\frac{3n+1}{2}$ )  $O_2$  → n  $CO_2$  + (n+1)  $H_2O$ 

- **1:** Hence, volume of O<sub>2</sub> required for complete combustion of an alkene, C<sub>n</sub>H<sub>2n</sub>, is directly proportional to the number of carbon atoms present.
- **2:** The same volume of CO<sub>2</sub> gas is produced for the complete combustion of the alkene, C<sub>n</sub>H<sub>2n</sub>, and alkane, C<sub>n</sub>H<sub>2n+2</sub>.
- **3:** Same volume of steam and CO<sub>2</sub> will be produced from the combustion of alkene.

- 32 Which of the following is an endothermic process?
  - 1 the condensation of steam
  - 2 the electrolysis of water
  - 3 the sublimation of iodine

## Answer: C

- **1:** Bond formation due to formation of water in liquid state (hydrogen bonds between water molecules) has occurred, thus condensation is an exothermic process.
- **2:** The electrolysis of water is an endothermic reaction (electrical energy supplied) with the following equation:  $2 H_2O(l) \rightarrow 2 H_2(g) + O_2(g)$
- **3:** I<sub>2</sub>(s) is converted to I<sub>2</sub> vapour and van der Waal's forces of attraction holding the I<sub>2</sub> molecules in a crystal lattice are broken. Thus it is an endothermic process.
- 33 Which of the following are correct statements about a catalysed reversible reaction?
  - 1 The catalyst alters the composition of equilibrium mixture.
  - 2 The catalyst alters the mechanism for the reaction.
  - 3 The catalyst reduces the activation energy for both the forward and backward reactions.

## Answer: C

A catalyst speeds up the reaction rate by providing an alternative reaction pathway with lower activation energy.

A catalyst has no effect on the position of equilibrium, and so, does not alter the composition of the equilibrium mixture. It simply speeds up the reaction so that equilibrium is reached faster.

**34** Which properties of aluminium chloride are related to its lack of an octet configuration in the A*l* atom?

# 1 its tendency to dimerise

- 2 its covalent character
- **3** its acidity in aqueous solution

# Answer: D

 $A/Cl_3$  dimerises to form  $Al_2Cl_6$  because  $A/Cl_3$  is two electrons short of an octet configuration. Hence one molecule forms dative covalent bond with another molecule by accepting a lone pair of electrons from the C*l* atom.

The high charge density of  $Al^{3+}$  accounts for its covalent character and acidity in aqueous solution ( $[Al(H_2O)_6]^{3+} \rightleftharpoons [Al(H_2O)_5(OH)]^{2+} + H^+$ ).

# 35 Use of the Data Booklet is relevant to this question.

An electrochemical cell is shown below.



Which of the following observations apply to the above cell?

# 1 The KI(aq) solution turns brown.

- 2 The  $E_{cell}^{\bullet}$  value is +0.14 V.
- **3** Effervescence is observed in the H<sub>2</sub>O<sub>2</sub> half-cell.

# Answer: D

The relevant half-equations from the Data Booklet are:

 $I_2(aq) + 2e^- \rightarrow 2I^-(aq)$  $E^{\theta} = +0.54 V$  $H_2O_2(aq) + 2H^+(aq) + 2e^- \rightarrow 2H_2O(l)$  $E^{\theta} = +1.77 V$ Since  $E^{\theta}_{H_2O_2/H_2O}$  is more positive  $EE^{\theta}_{I_2/I^-}$ ,  $H_2O_2$  oxidises I to I2 while itself is reduced to

H<sub>2</sub>O.

Thus  $E_{cell}^{\Theta}$  = +1.77 – 0.54 = +1.23 V

1  $H_2$ 2  $H_2$ 4  $H_2SO_4$ 6  $H_2SO_4$ 7  $H_2SO_4$ 

**36** Which of the following reactions will not give a good yield of the desired product?

# **Answer: B**

1 Although there is only one kind of hydrogen that can undergo free radical substitution in the compound, the alkene functionality can also undergo



electrophilic addition with Br2, thus forming

2 The alkene undergoes oxidative cleavage to give -CO<sub>2</sub>H on both ends, sidechain oxidation of alkylbenzene also occurs, resulting in a good yield of



**3** The alkene undergoes electrophilic addition with Br<sub>2</sub> in CCl<sub>4</sub> to give the stated product in good yield. There is no other nucleophile apart from Br<sup>-</sup> (unlike for Br<sub>2</sub>(aq) where there is H<sub>2</sub>O) available to attack the carbocation intermediate.



# **Answer: A**

The ester groups in the compounds will undergo hydrolysis under hot aqueous sodium hydroxide. Due to the alkaline medium, phenoxide and carboxylate ions are formed.

- 1 The acyl chloride group hydrolyses in aqueous solution (sodium hydroxide need not be present) to give carboxylic acid, which becomes carboxylate due to the alkaline medium.
- 2 This compound has two consecutive ester groups within the ring on the right. Both are hydrolysed.
- **3** The phenol group undergoes acid-base reaction in the alkaline medium to become phenoxide.

**38** Allantoin is known to have a soothing and moisturizing effect on human skin and is commonly included in cosmetics and skincare products.



allantoin

Which of the following is true of allantoin?

- 1 It is optically inactive.
- 2 An aqueous solution of allantoin is approximately neutral.
- **3** Hydrolysis of allantoin gives an  $\alpha$ -amino acid as one of the products.

#### Answer: C

 Allantoin has a chiral carbon as shown: O<sup>±</sup> Hence, it is optically active.



2 All nitrogen atoms on allantoin are found adjacent to carbonyl groups (C=O). Thus these are all amide groups and the lone pair of electrons on each nitrogen can delocalize into the C=O π bond:



This makes the lone pairs of electrons on the nitrogens less available to donate to H<sup>+</sup>, and hence, allantoin is not basic, but neutral.

**3** Hydrolysis of allantoin gives the following products:



including an amino acid with  $-CO_2H$  and  $-NH_2$  attached to the same carbon atom ( $\alpha$ -amino acid).

**39** Which deductions about the reactions of 4-phenylcoumarin can be made from its structure?



- 1 Upon hydrolysis, the organic product reacts with 3 moles of  $Br_2(aq)$ .
- 2 It reacts with cold acidified KMnO<sub>4</sub> to give a chiral product.
- 3 It can undergo both nucleophilic substitution and nucleophilic addition.

#### **Answer: B**

1 After hydrolysis of the ester group, Br<sub>2</sub> adds across the C=C bond (electrophilic addition) and substitutes onto the phenol (electrophilic substitution). With Br<sub>2</sub>(aq), substitution occurs on the phenol at the 2- and 4-positions (the 6-position is blocked by the alkyl side-chain). Hence the reaction is with 3 moles of Br<sub>2</sub>.



2 Cold acidified KMnO<sub>4</sub> will result in oxidative addition (mild oxidation), where –OH is added across the C=C double bond to give the following product, which has 2 chiral centres (marked with \*):



- 3 The reactions are not nucleophilic, but **electrophilic** addition and **electrophilic** substitution as the alkene and benzene rings are both electron-rich.
- **40** The Vilsmeier-Haack reaction is the chemical reaction of an amide with an electron-rich arene to produce an aryl aldehyde or ketone. The reaction occurs with the aid of phosphorus oxychloride,  $POCl_3$ , (which is not shown) in the equation below:



Which of the following is an example of a Vilsmeier-Haack reaction?



# Answer: C

While there is a variety of amide reactants as well as aldehydes and ketones formed in the three options given, the most important detail from the description of the Vilsmeier-Haack reaction in the question is that an electron-rich arene is necessary in order for this reaction to work.

- 1 the –NO<sub>2</sub> should be immediately recognised as an electron-withdrawing group.
- 2 the –OCH<sub>3</sub> group, while not immediately familiar, is saturated and there are lone pairs on O. Thus it is an electron-donating group.
- **3** the arene is made up of three benzene rings fused together, and these might function similar to side-chain alkyl groups in being electron-donating.

Thus the reaction should work for option 2 but not option 1, and the best answer is C.