**RAFFLES INSTITUTION**
**2013 YEAR 6 PRELIMINARY EXAMINATION**

**HIGHER 2**

# CHEMISTRY 9647/01

**Paper 1 Multiple Choice** **27 September 2013**

**1 hour**

Additional Materials: Multiple Choice Answer Sheet
Data Booklet

**READ THESE INSTRUCTIONS FIRST**

**Do not open this question booklet until you are told to do so.**

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

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 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.

This document consists of **23** printed pages.

## Section A

For each question there are four possible answers, **A**, **B**, **C**, and **D**. Choose the **one** you consider to be correct.

**1** Which expression correctly defines the term *relative atomic mass of an element*?

**A** the mass of 1 mole of atoms of an element divided by $6.02 \times 10^{23}$

**B** the mass of 1 atom of an element relative to the mass of $\frac{1}{12}$ of a $^{12}C$ atom

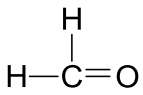
**C** the average mass of 1 atom of an element relative to the mass of $\frac{1}{12}$ of a $^{12}C$ atom

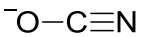
**D** the average mass of 1 mole of atoms of an element relative to the mass of a $^{12}C$ atom

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

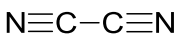
Potassium manganate(VII), $KMnO_4$, reacts with sodium cyanide, NaCN, in a molar ratio of 2:3 to form manganese(IV) oxide, $MnO_2$.

Which of the following would be the carbon-containing product in this reaction?

**A** 

**B** 

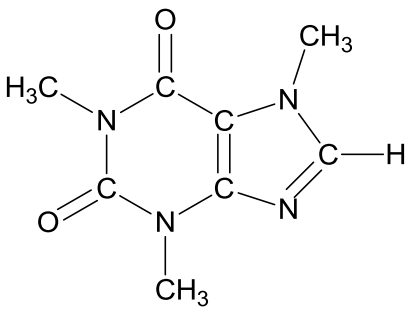
**C** 

**D** 

**3** For which of the following pairs does species **I** have a smaller bond angle than species **II**?

| | **I** | **II** |
|---|---|---|
| **A** | $NO_3^-$ | $NO_2^-$ |
| **B** | $SF_6$ | $ClF_3$ |
| **C** | $XeF_4$ | $BrF_5$ |
| **D** | $BrO_3^-$ | $ClO_3^-$ |

**4** To produce decaffeinated coffee, pure liquid $CO_2$ is sometimes used to extract caffeine from coffee beans.



caffeine

It was discovered that the solubility of caffeine greatly increased when a mixture of ethanol and liquid $CO_2$ (ethanol–$CO_2$ mixture) was used.

Which interaction best explains why caffeine is more soluble in the ethanol–$CO_2$ mixture as compared to liquid $CO_2$?

**A** hydrogen bonding
**B** dative covalent bonding
**C** permanent dipole – permanent dipole interactions
**D** instantaneous dipole – induced dipole interactions

**5** For a fixed mass of an ideal gas, which of the following graphs does **not** have the same general shape as the rest?

($\rho$ = density of the gas; $M$ = molar mass of gas)

**A** $\frac{P}{\rho}$ against $T$ **B** $PV$ against $\frac{M}{T}$

**C** $P$ against $\rho T$ **D** $\frac{T}{P}$ against $V$

**6** When 1 mole of carbon dioxide gas solidifies as dry ice, 25.2 kJ of heat energy is evolved. The sublimation temperature of carbon dioxide is −78.5 °C.

What is the entropy change when 132 g of carbon dioxide gas solidifies at this temperature?

**A** −389 J $K^{-1}$ **B** −130 J $K^{-1}$

**C** +130 J $K^{-1}$ **D** +389 J $K^{-1}$

**7** Given the following thermochemical data, calculate the standard enthalpy change of the reaction, $\Delta H_r^{\ominus}$.

$$CH_3C{\equiv}CCH_3\,(g) \xrightarrow{\Delta H_r^{\ominus}} CH_2{=}CHCH{=}CH_2\,(g)$$

| | |
|---|---|
| Standard enthalpy change of combustion of $CH_3C{\equiv}CCH_3(g)$ | = –2577 kJ mol$^{-1}$ |
| Standard enthalpy change of combustion of carbon | = –394 kJ mol$^{-1}$ |
| Standard enthalpy change of combustion of hydrogen | = –286 kJ mol$^{-1}$ |
| Standard enthalpy change of formation of $CH_2{=}CHCH{=}CH_2(g)$ | = +110 kJ mol$^{-1}$ |

**A** –253 kJ mol$^{-1}$ **B** –33 kJ mol$^{-1}$

**C** +33 kJ mol$^{-1}$ **D** +253 kJ mol$^{-1}$

**8** Pentaamminechlorocobalt(III) ions and hydroxide ions react as follows:

$$[Co(NH_3)_5Cl]^{2+}(aq) + OH^-(aq) \longrightarrow [Co(NH_3)_5OH]^{2+}(aq) + Cl^-(aq)$$

The variation for the initial rate of reaction with the concentrations of the reactants was investigated in three experiments.

| experiment | $[Co(NH_3)_5Cl^{2+}]$ / mol dm$^{-3}$ | $[OH^-]$ / mol dm$^{-3}$ | initial rate / mol dm$^{-3}$ s$^{-1}$ |
|---|---|---|---|
| 1 | 0.20 | 0.30 | 0.364 |
| 2 | 0.40 | 0.30 | 0.727 |
| 3 | 0.10 | 0.45 | 0.273 |

Based on the above data, which of the following statements is correct?

**A** The rate of reaction is pH dependent.

**B** The overall order of the reaction is one.

**C** The units of the rate constant are mol$^{-2}$ dm$^6$ s$^{-1}$.

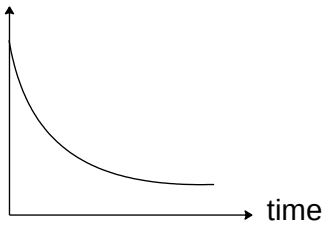
**D** The activation energy of the reaction is lowered by using a concentrated alkali.

**9** The reaction between acidified KI and aqueous $H_2O_2$ involves the following steps:

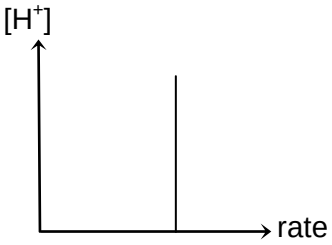
$$H_2O_2 + I^- \longrightarrow H_2O + OI^- \quad \text{slow}$$
$$OI^- + H^+ \longrightarrow HOI \quad \text{fast}$$
$$HOI + H^+ + I^- \longrightarrow I_2 + H_2O \quad \text{fast}$$

Which graph would be obtained?

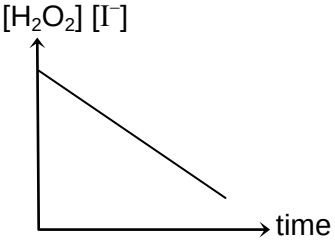
**A**



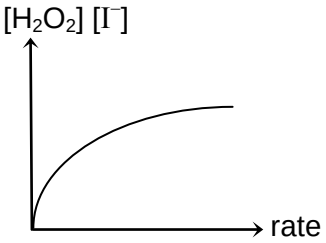

**B**




**C**




**D**




**10** Methylamine, $CH_3NH_2$, is a weak base.

When 40 $cm^3$ of 0.10 mol $dm^{-3}$ HC*l* is added to 20 $cm^3$ of 0.30 mol $dm^{-3}$ $CH_3NH_2$, the pH of the resulting solution obtained is 10.5.

Given $K_w = 1.00 \times 10^{-14}$ $mol^2$ $dm^{-6}$, what is the p$K_b$ of methylamine, $CH_3NH_2$?

**A** 3.20

**B** 3.50

**C** 5.20

**D** 10.5

**11** A solution consists of 0.10 mol $dm^{-3}$ $MgSO_4$ and 0.10 mol $dm^{-3}$ $FeSO_4$. It is suggested that the metal ions can be separated as their hydroxides.

At 298 K, the solubility product of $Mg(OH)_2$ is $7.1 \times 10^{-12}$ $mol^3$ $dm^{-9}$ and that of $Fe(OH)_2$ is $4.1 \times 10^{-15}$ $mol^3$ $dm^{-9}$.

What would be the pH of the resultant solution when maximum separation has occurred?

**A** 7.05

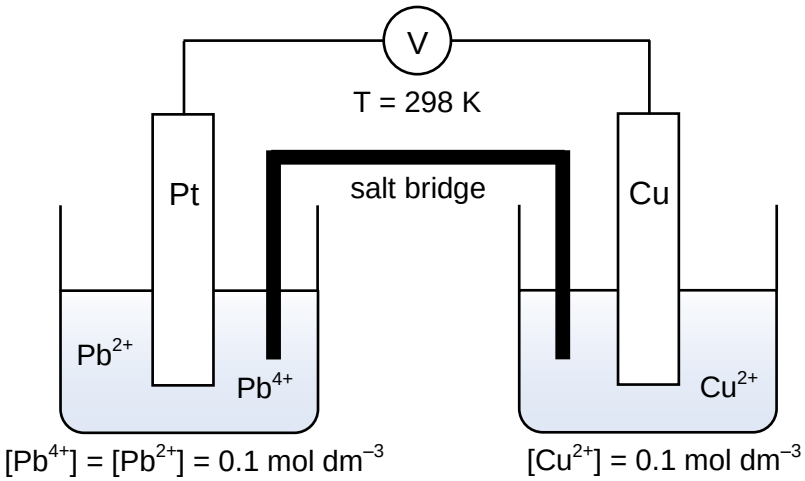
**B** 8.93

**C** 10.1

**D** 13.4

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

An electrochemical cell is set up as shown:




Which statement about the e.m.f. of the above cell is correct?

**A** The e.m.f of the cell is +1.35 V.

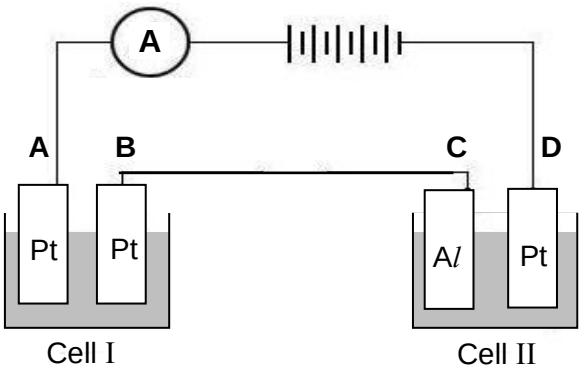
**B** Addition of water to the $Pb^{4+}/Pb^{2+}$ half cell increases the e.m.f of the cell.

**C** Decreasing the mass of the copper electrode decreases the e.m.f of the cell.

**D** Addition of excess aqueous ammonia to the $Cu^{2+}/Cu$ cell increases the e.m.f of the cell.

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

A student carried out an experiment involving the electrolysis of aqueous copper(II) sulfate in Cell I and aqueous sulfuric acid in Cell II.




0.00417 moles of copper was deposited at electrode **B** after electrolysis.

Given that relative formula mass of $Al_2O_3$ is 102.0, what is the maximum mass of $Al_2O_3$ formed at electrode **C**?

**A** 0.142 g

**B** 0.426 g

**C** 0.639 g

**D** 0.851 g

**14** Tetrachloromethane, $CCl_4$, does not react with water under normal conditions, while silicon tetrachloride, $SiCl_4$, is completely hydrolysed by water to give $SiO_2$ and $HCl$.

Which statement best explains the differences in reactivity between $CCl_4$ and $SiCl_4$?

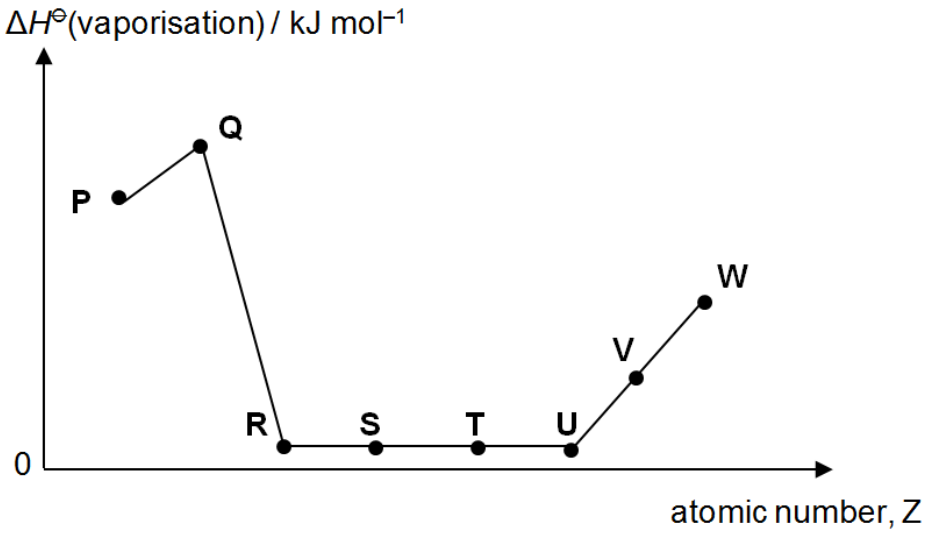
**A** The C–Cl bond is stronger than the Si–Cl bond.

**B** The Si–Cl bond is more polar than the C–Cl bond.

**C** Silicon possesses low–lying empty d orbitals but not carbon.

**D** $SiCl_4$ forms stronger van der Waals' interactions with water than $CCl_4$.

**15** The graph below shows the variation in the standard enthalpy change of vaporisation, $\Delta H^{\ominus}$(vaporisation), for eight consecutive elements in the Periodic Table, all with atomic number, Z ≤ 20.




Which statement is correct?

**A** Element **Q** forms an oxide which is amphoteric.

**B** Element **R** forms an oxide which is basic in aqueous solution.

**C** Element **V** forms a chloride which is neutral in aqueous solution.

**D** Element **W** forms a chloride which is basic in aqueous solution.

**16** Lithium compounds behave in a similar way as magnesium compounds in that they produce oxides when subjected to thermal decomposition.

1.0 mol of each of the following compounds is strongly heated and any gas produced is collected at 150 °C and 1 atm.

Which compound is likely to give the largest volume of gas?

**A** LiOH **B** $LiNO_3$ **C** $Mg(OH)_2$ **D** $Mg(NO_3)_2$

**17** Which statement about the trends in the properties of the halogens is correct?

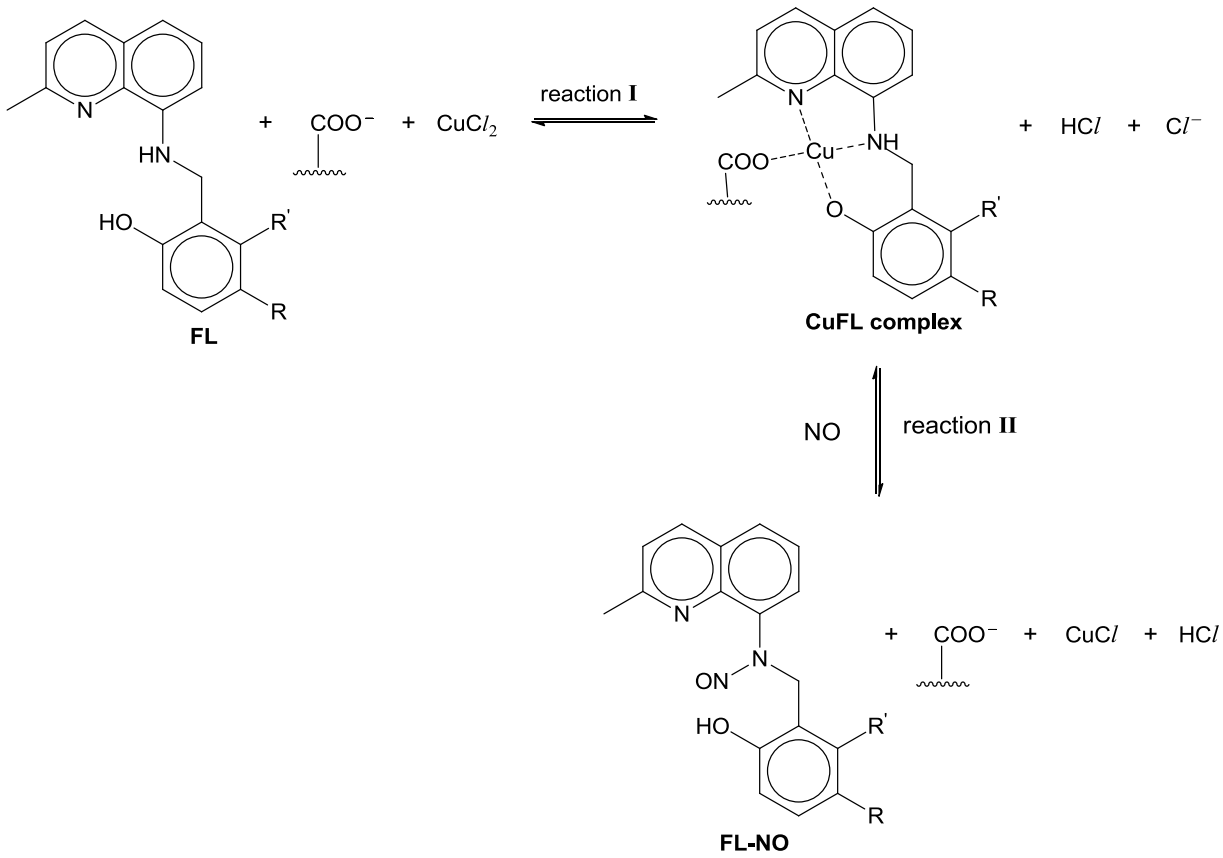
**A** The volatility of halogens increases down the group.

**B** The electronegativity of halogens increases down the group.

**C** The reactivity of halogens with hydrogen decreases down the group.

**D** The bond dissociation energy of halogens increases down the group.

**18** CuFL, a copper(II) complex, reacts with the anionic carboxylate group from a biological receptor as shown in the reaction scheme below.




What can be deduced from the above information?

**A** **FL** is a bidentate ligand.

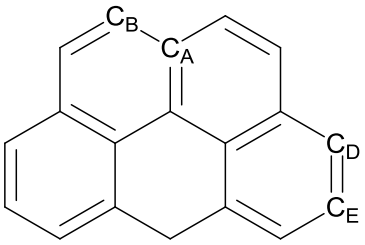
**B** Reaction **II** is a redox reaction.

**C** Copper(II) ions only form ionic bonds in the **CuFL complex**.

**D** The colour of the equilibrium mixture is due to d–d transitions in CuCl.

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

Olympicene was conceived in March 2010 as a way to celebrate the 2012 London Olympics. Its structure is shown below.




olympicene

Which statement is correct?

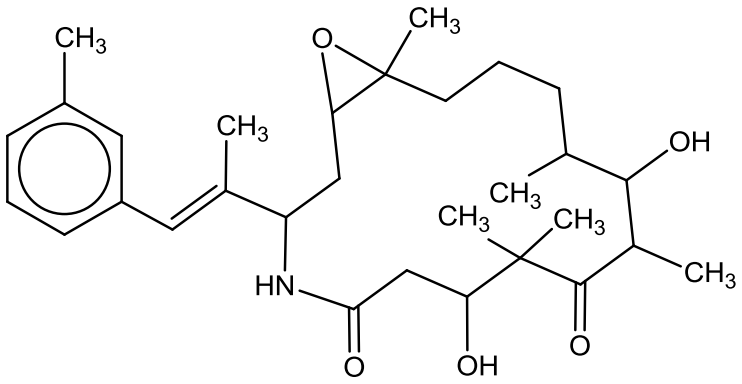
**A** Olympicene is a planar molecule.

**B** Olympicene has a molecular formula of $C_{18}H_{12}$.

**C** The melting point of olympicene is lower than that of graphite.

**D** The bond energies of the $C_A$–$C_B$ bond and $C_D$–$C_E$ bond are 350 kJ $mol^{-1}$ and 610 kJ $mol^{-1}$ respectively.

**20** Compound **X** is an analogue of Ixabepilone which is an anticancer agent currently in clinical development.




compound **X**

Compound **X** was reacted with $NaBH_4$ in methanol.

In this reaction, the 

ring remains unaltered.

What is the maximum number of stereoisomers in the product of this reaction?

**A** $2^7$ **B** $2^8$ **C** $2^9$ **D** $2^{10}$

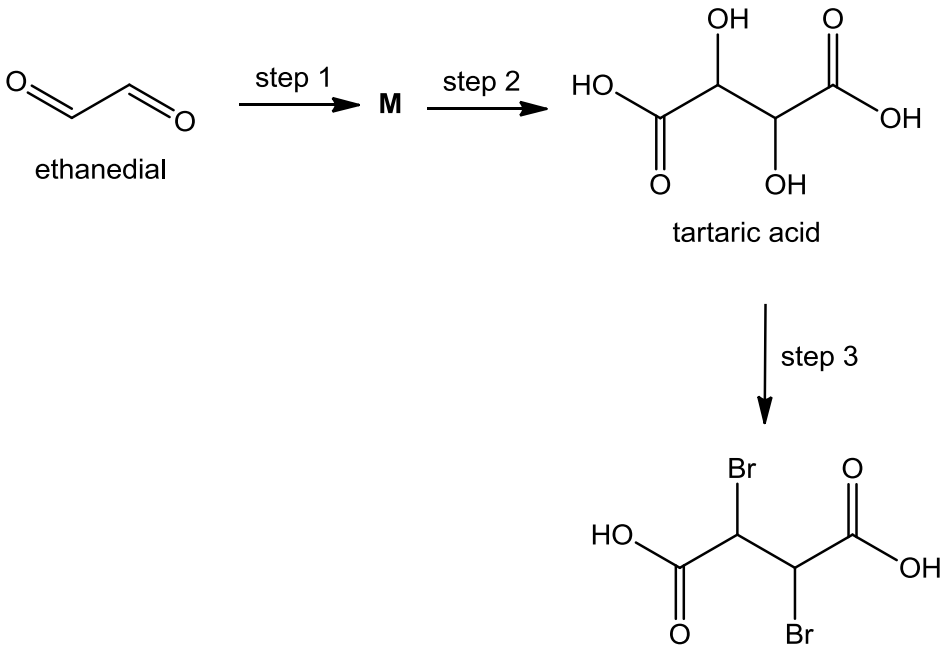
**11**

**21** When an alkane **E** ($C_7H_{16}$) is reacted with bromine under ultraviolet light, only three isomeric monobromo compounds **F**, **G** and **H** with the formula $C_7H_{15}Br$ are produced. Only compound **H** is chiral.

What are the structures of **E** and **H**?

| | **E** | **H** |
|---|---|---|
| **A** | $(CH_3)_3CCH(CH_3)_2$ | $(CH_3)_3CCBr(CH_3)_2$ |
| **B** | $CH_3CH_2CH(CH_2CH_3)_2$ | $CH_3CHBrCH(CH_2CH_3)_2$ |
| **C** | $(CH_3)_2CHCH_2CH(CH_3)_2$ | $(CH_3)_2CHCHBrCH(CH_3)_2$ |
| **D** | $(CH_3)_2CHCH(CH_3)CH_2CH_3$ | $(CH_3)_2CHCBr(CH_3)CH_2CH_3$ |

**22** Refer to the reaction scheme below.




Which of the following gives the correct reagent(s) and condition(s) for each step?

| | step 1 | step 2 | step 3 |
|---|---|---|---|
| **A** | hot ethanolic KCN | hot dilute $H_2SO_4$ | NaBr, conc $H_2SO_4$, heat |
| **B** | hot ethanolic KCN | hot acidified $KMnO_4$ | $SOBr_2$ |
| **C** | cold HCN, trace KCN | hot dilute $H_2SO_4$ | NaBr, conc $H_2SO_4$, heat |
| **D** | cold HCN, trace KCN | hot acidified $KMnO_4$ | $SOBr_2$ |

**23** Which one of the following sequences of reactions is expected to give the best yield for the synthesis of 2-bromo-4-nitromethylbenzene from benzene?

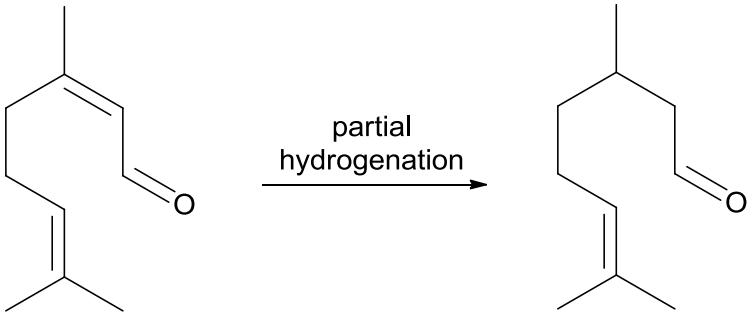
**A** alkylation, bromination, nitration

**B** alkylation, nitration, bromination

**C** nitration, alkylation, bromination

**D** nitration, bromination, alkylation

**24** Citral can be partially hydrogenated to form citronellal as shown:




citral citronellal

Which of the following can be used to distinguish between citral and citronellal?

**A** liquid bromine

**B** cold neutral potassium manganate(VII)

**C** Fehling's solution

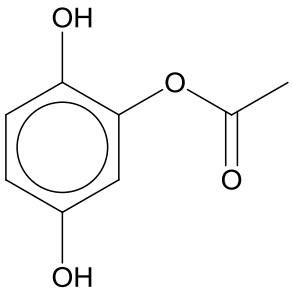
**D** hot acidified potassium manganate(VII)

**25** A compound **J**, $C_8H_8O_4$, undergoes the following reactions:

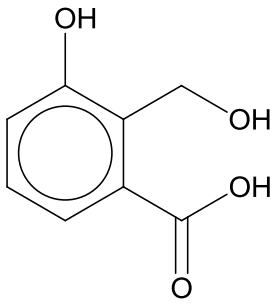
- 1 mole of **J** reacts completely with 2 moles of cold aqueous NaOH.
- 1 mole of **J** reacts completely with 2 moles of $PCl_5$ to give misty fumes.
- **J** reacts with hot concentrated $H_2SO_4$ to form a compound, $C_8H_6O_3$.

Which of the following could be **J**?

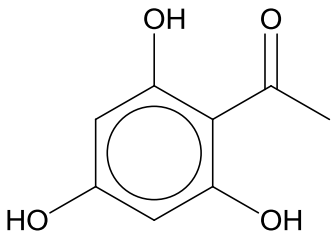
**A**



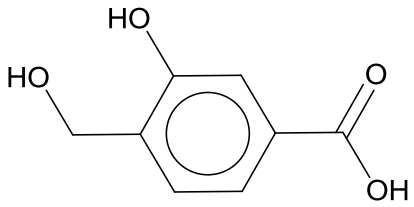

**B**




**C**

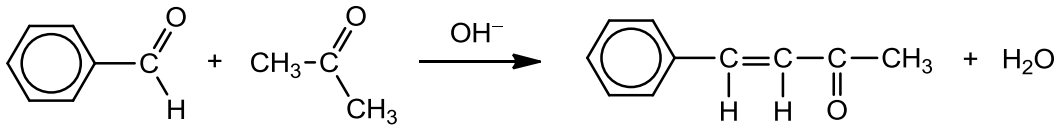



**D**

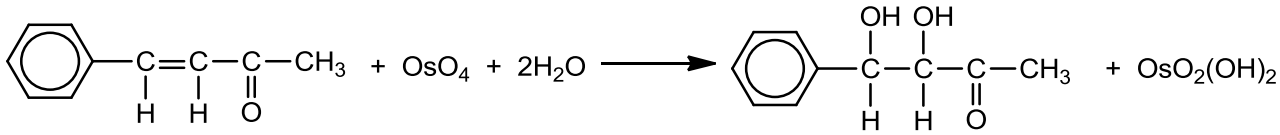


**26** Benzaldehyde undergoes a 3-step synthesis to form compound **P** as shown below.

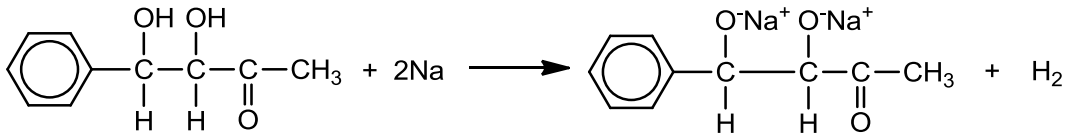
Step 1:



Step 2:



Step 3:



compound **P**

Which of the following describes the types of reactions taking place in each step?

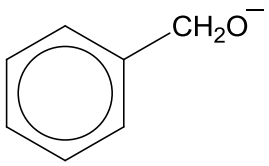
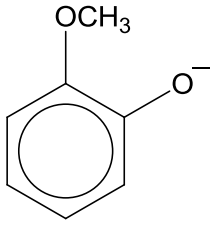
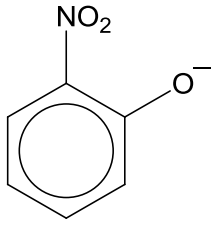
| | Step 1 | Step 2 | Step 3 |
|---|---|---|---|
| **A** | condensation | redox | redox |
| **B** | condensation | electrophilic addition | acid-base |
| **C** | addition | electrophilic addition | redox |
| **D** | addition | redox | acid-base |

**27** A student carried out an experiment to study the ease of hydrolysis of a series of chlorinated compounds, and recorded the observations based on the addition of acidified silver nitrate solution.

Which of the following gives the expected results?

| | time taken for precipitate to appear<br>shortest → longest | | | |
|---|---|---|---|---|
| **A** | $C_6H_5Cl$ | $CH_2ClCONH_2$ | $CH_3COCl$ | $COCl_2$ |
| **B** | $CH_2ClCONH_2$ | $C_6H_5Cl$ | $COCl_2$ | $CH_3COCl$ |
| **C** | $CH_3COCl$ | $COCl_2$ | $C_6H_5Cl$ | $CH_2ClCONH_2$ |
| **D** | $COCl_2$ | $CH_3COCl$ | $CH_2ClCONH_2$ | $C_6H_5Cl$ |

**28** Which of the following shows the given species arranged in order of increasing p$K_b$ values?

| $CH_3CHClCOO^-$ |  |  |  |
|---|---|---|---|
| **I** | **II** | **III** | **IV** |

**A** **I**, **III**, **IV**, **II**

**B** **I**, **IV**, **III**, **II**

**C** **II**, **III**, **IV**, **I**

**D** **II, IV, III, I**

**29** Benzylamine has the formula $C_6H_5CH_2NH_2$ and is a common precursor in organic synthesis.

Which of the following statements about benzylamine is correct?

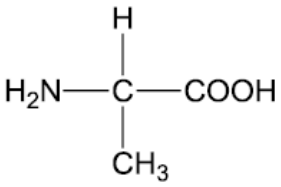
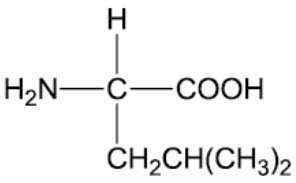
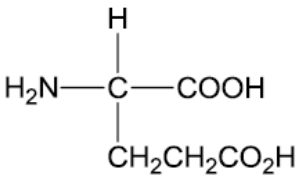
**A** It decolourises aqueous $Br_2$.

**B** It can be produced by reduction of $C_6H_5CH_2CN$.

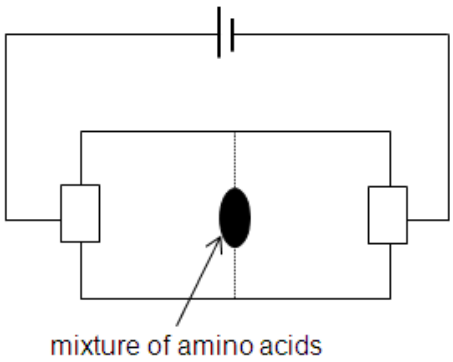
**C** It reacts with $CH_3COOH$ to form $C_6H_5CH_2NHCOCH_3$.

**D** It reacts with excess $CH_3CH_2Cl$ to form the compound, $C_{13}H_{22}NCl$.

**30** The table below gives some information pertaining to three amino acids.

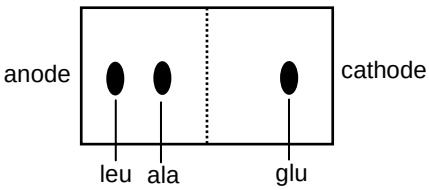
| amino acid | structure | isoelectric point |
|---|---|---|
| alanine (ala) |  | 6.0 |
| leucine (leu) |  | 6.0 |
| glutamic acid (glu) |  | 3.2 |

A mixture of these three amino acids can be separated by electrophoresis.

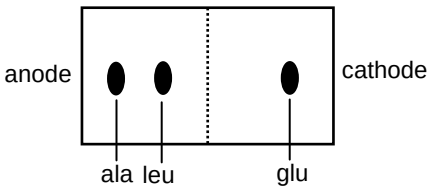



Which of the following diagram shows the result of the separation of the amino acid mixture at pH 5.0?

**A**



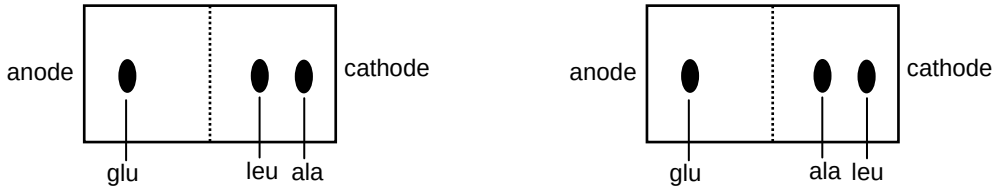

**B**




**C**

**D**

**17**




## 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

| A | B | C | D |
|---|---|---|---|
| **1, 2** and **3** are correct | **1** and **2** only are correct | **2** and **3** only are correct | **1** only is correct |

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

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

**M** and **N** have the following features:

- **M** has fewer unpaired electrons than **N**.
- **M** is smaller than **N**.

Which of the following pairs of **M** and **N** possess these features?

| | M | N |
|---|---|---|
| **1** | $S^-$ | $P^-$ |
| **2** | Mg | A*l* |
| **3** | $Zn^{2+}$ | $Cu^+$ |

**32** When steam is passed over white hot coke, a mixture of combustible gases is obtained.

$$C(s) + H_2O(g) \rightleftharpoons H_2(g) + CO(g); \qquad \Delta H = +131 \text{ kJ mol}^{-1}$$

When equilibrium has been established, which of the following correctly describes what would happen if a proposed change is made to this system?

| | proposed change | value of $K_c$ | forward rate constant | backward rate constant |
|---|---|---|---|---|

| | | | | |
|---|---|---|---|---|
| **1** | add catalyst | no change | increase | increase |
| **2** | add more C(s) | no change | increase | no change |
| **3** | increase temperature | increase | increase | decrease |

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

| A | B | C | D |
|---|---|---|---|
| **1, 2** and **3** are correct | **1** and **2** only are correct | **2** and **3** only are correct | **1** only is correct |

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

**33** Phosphorus pentachloride, $PCl_5$, is prepared from the chlorination of $PCl_3$ according to the equation below.

$$PCl_3(g) + Cl_2(g) \rightleftharpoons PCl_5(g); \qquad \Delta H = -124 \text{ kJ mol}^{-1}$$

At a constant temperature and a total initial pressure of 2.4 atm, a 1 : 2 mixture of $PCl_3$ and $Cl_2$ is allowed to reach equilibrium in a sealed vessel. The percentage yield is found to be 40%.

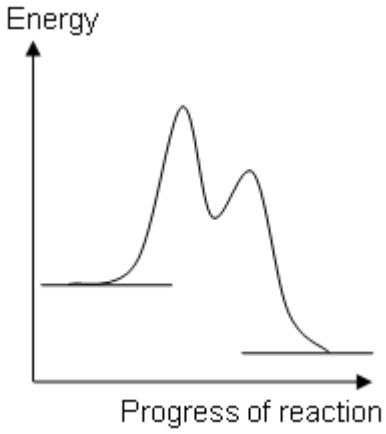
Which of the following are correct?

**1** $PCl_5$ has a trigonal bipyramidal shape.

**2** The equilibrium constant, $K_p$, is found to be 0.521 $\text{atm}^{-1}$.

**3** When the total volume of the vessel is increased, the percentage yield decreases.

**34** The energy profile diagram of a reaction is shown below.




Which of the following reactions have the same energy profile shown above?

trace amount of KCN(aq)
cold

**19**

**1** $CH_3CHO + HCN \longrightarrow CH_3CH(OH)CN$

**2** $(CH_3)_3CBr + KOH \xrightarrow{\text{heat}} (CH_3)_3COH + KBr$

**3** $CH_3I + NaOH \xrightarrow{\text{heat}} CH_3OH + NaI$

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

| A | B | C | D |
|---|---|---|---|
| **1, 2** and **3** are correct | **1** and **2** only are correct | **2** and **3** only are correct | **1** only is correct |

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

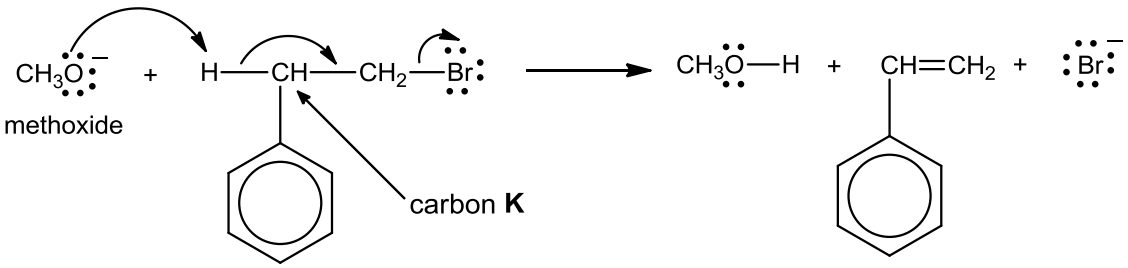
**35** Which of the following statements about potassium iodide are correct?

**1** When reacted with concentrated sulfuric acid, it gives pungent smelling gases and a dark brown solution containing a yellow precipitate.

**2** It can be formed when aqueous potassium hydroxide is added to iodine.

**3** It is a weaker reducing agent than potassium chloride.

**36** Refer to the reaction below.




Which of the following statements are correct?

**1** The methoxide ion is the Brønsted base.

**2** The hybridisation of carbon **K** has changed from $sp^3$ to $sp^2$.

**3** The reaction involves the breaking and formation of two $\sigma$ bonds.

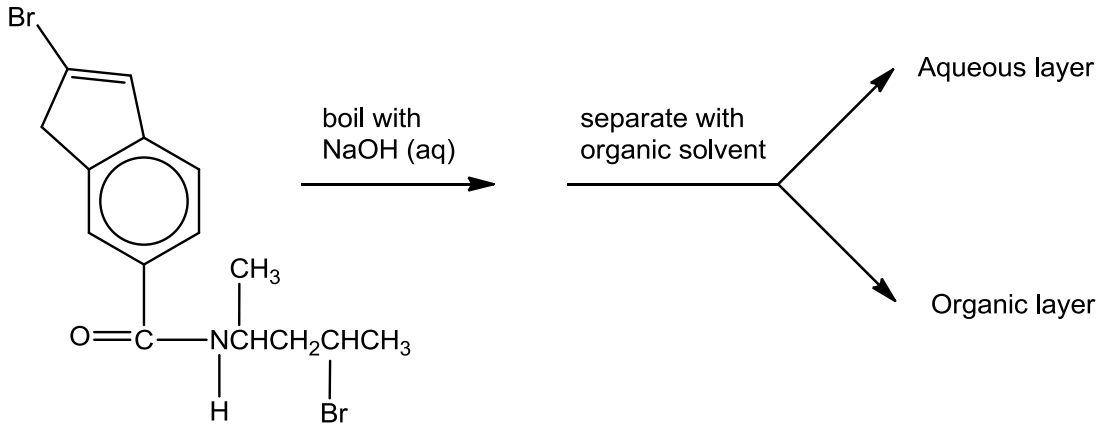
**20**

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

| A | B | C | D |
|---|---|---|---|
| **1, 2** and **3** are correct | **1** and **2** only are correct | **2** and **3** only are correct | **1** only is correct |

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

**37** 1 mole of compound **N** was boiled with aqueous sodium hydroxide, and the resulting reaction mixture was shaken with an organic solvent.




compound **N**

Which of the following statements are correct?

**1** The compound in the organic layer has 4 stereoisomers.

**2** The compound in the organic layer turns hot acidified $K_2Cr_2O_7$ from orange to green.

**3** When the aqueous layer is treated with acidified $AgNO_3$, 1 mole of cream precipitate is obtained.

**21**

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

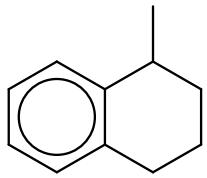
| A | B | C | D |
|---|---|---|---|
| **1, 2** and **3** are correct | **1** and **2** only are correct | **2** and **3** only are correct | **1** only is correct |

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

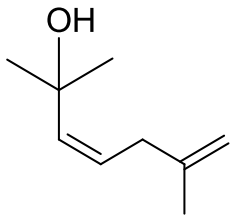
**38** An organic compound **L** was subjected to prolonged heating with excess acidified potassium manganate(VII). After the entire treatment, a dicarboxylic acid was amongst the products found.

Which of the following could be **L**?

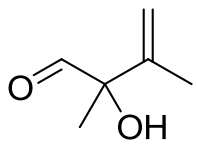
**1**



**2**




**3**



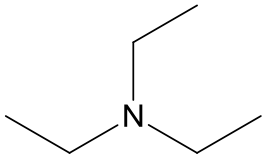
**22**

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

| A | B | C | D |
|---|---|---|---|
| **1, 2** and **3** are correct | **1** and **2** only are correct | **2** and **3** only are correct | **1** only is correct |

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

**39** Triethylamine is a useful starting material for many organic reactions.




triethylamine

Which of the following statements about triethylamine are correct?

**1** It will form an addition product with $BF_3$.

**2** It will form an amide with ethanoyl chloride.

**3** It has a higher boiling point than hexylamine due to stronger hydrogen bonding.

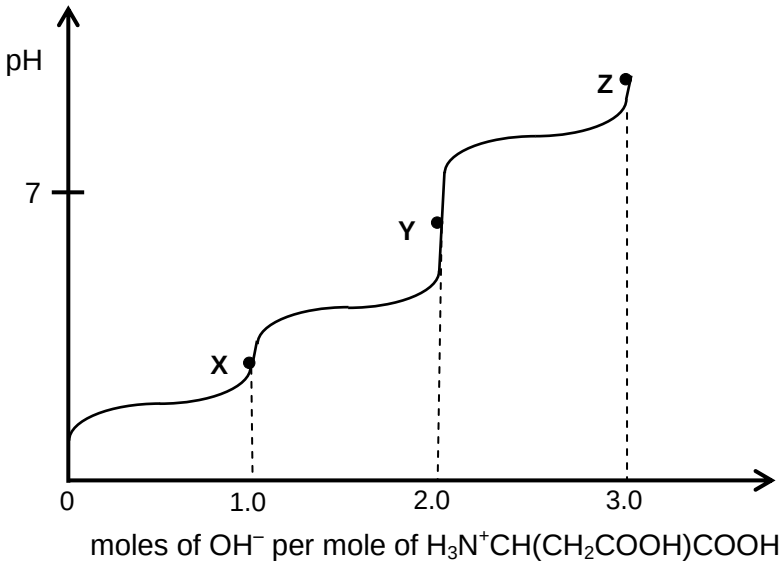
**23**

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

| A | B | C | D |
|---|---|---|---|
| **1, 2** and **3** are correct | **1** and **2** only are correct | **2** and **3** only are correct | **1** only is correct |

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

**40** The titration curve of the protonated form of aspartic acid, $H_3N^+CH(CH_2COOH)COOH$, is shown. The p$K_a$ values associated with aspartic acid are 2.09, 3.86 and 9.82.




Which of the following statements are correct?

**1** The pH at point **Y** is 6.84.

**2** There is no net charge on the amino acid at point **X**.

**3** Equal concentrations of $H_3N^+CH(CH_2COO^-)COO^-$ and $H_2NCH(CH_2COO^-)COO^-$ are present at pH 9.82.

**– END OF PAPER –**