ST ANDREW'S JUNIOR COLLEGE
JC2 PRELIMINARY EXAMINATIONS
HIGHER 1

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| CANDIDATE NAME | |
| CLASS | 2 3 S |

# CHEMISTRY 8873/01

Paper 1 Multiple Choice **11 September 2024**
Candidate answer on the Optical Answer Sheet **1 hour**
Additional Materials: Data Booklet

**READ THESE INSTRUCTIONS FIRST**

Write in soft pencil.

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

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 Optical Answer Sheet.

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 (including this cover page).

**1** Oxygen exist as two isotopes; $^{16}O$ and $^{18}O$ respectively. Which of the following particles contain more neutrons than protons and more protons than electrons respectively?

1 $^{12}C^{18}O_3^{2-}$

2 $^{1}H_3^{16}O^{+}$

3 $^{14}N^{18}O^{+}$

**A** 1, 2 and 3

**B** 1 and 2 only

**C** 2 and 3 only

**D** 3 only

**Ans: D**

Option 1 is wrong because the particle have a negative charge, implying that the number of electrons is more than the number of protons.

Option 2 is wrong because $^{16}O$ has similar number of protons and neutrons and $^{1}H$ has more proton than neutron even though there is more proton than electron due to the positive charge.

Option 3 is correct because $^{18}O$ in $N^{18}O^{+}$ has 2 more neutrons than protons, and 1 more proton than electron.

**2** The first seven successive ionisation energies for element **X** are as shown. **X** is found in Period 3.

| | 1st | 2nd | 3rd | 4th | 5th | 6th | 7th |
|---|---|---|---|---|---|---|---|
| Ionisation energy / kJ $mol^{-1}$ | 1010 | 1900 | 2900 | 5000 | 6300 | 21300 | 25400 |

Which compound can be formed using **X**?

**A** **X**O **B** **X**$O_2$ **C** **X**$O_3$ **D** $X_4O_{10}$

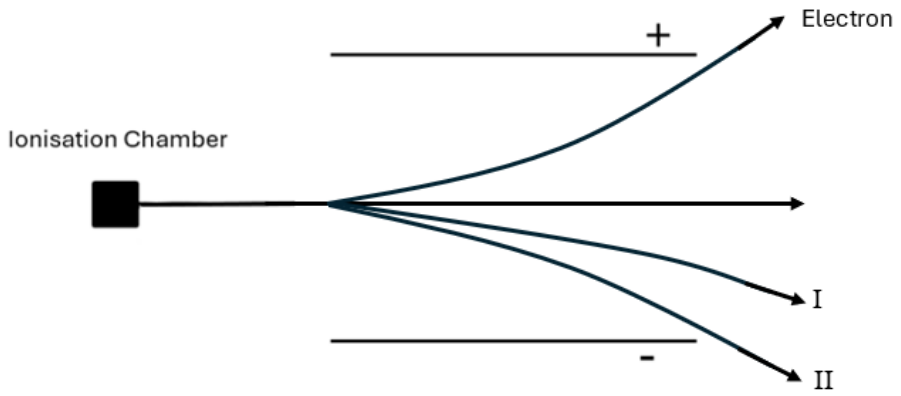
**Ans: D**

There is a large jump in ionisation energy from 5th to 6th, which implies that the 6th electron comes from an inner shell that is closer to nucleus and will experience stronger nuclear attraction. Hence, **X** has 5 valence electrons and is from Group 15. As a period 3 element, it is able to form $X_4O_{10}$ (ie $P_4O_{10}$).

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

$^{204}_{81}Tl$ can undergo natural radioactive decay, where one of its electrons enters the nucleus to change a proton into a neutron, to form a new element **X**.

When **X** is put in an ionisation chamber, it emits a high energy $\alpha$-particle (which is a $^{4}He$ nucleus).




What is the identity of the element **X** and the path of the emitted $\alpha$-particle in an electric field?

| | **X** | Deflection Path |
|---|---|---|
| **A** | $^{204}_{80}X$ | I |
| **B** | $^{204}_{82}X$ | II |
| **C** | $^{205}_{80}X$ | I |
| **D** | $^{205}_{82}X$ | II |

**Ans: A**

Based on the radioactive decay, the proton number will drop by 1. But however, the nucleon number will remain the same as there is now 1 more neutron. Hence, X is $^{204}_{80}X$.

Angle of deflection α |q/m|

q/m for He nucleus = 2/4 = 0.5

q/m for electron = 1/(1/1840) = 1840

Hence, the angle of deflection for the α-particle will be smaller than that of electron.

Hence I is the deflection path for the α-particle.

**4** Which statements about cyanogen molecule, $(CN)_2$, are correct?

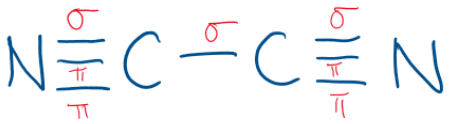
1 $(CN)_2$ is polar.
2 $(CN)_2$ is bent at the central carbon atoms.
3 A $(CN)_2$ molecule has 3 σ and 4 π bonds.
4 A $(CN)_2$ molecule has a total of 26 electrons.

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

**Ans: D**

Option 1 is wrong as the molecule is linear and the individual dipole moment from C to N are opposite and equal to each other, thus resulting in its cancellation.

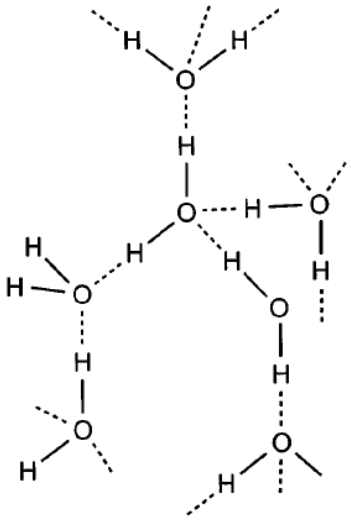
Option 2 is wrong as the molecule is linear (ie. 2 bond pairs and 0 lone pair around each C).



Option 3 is correct.

Option 4 is correct as 7 + 7 + 6 + 6 = 26.

**5** The structure of ice is as shown.



Which statement is **incorrect**?

**A** The open structure causes ice to be less dense than liquid water.

**B** The open structure gives ice a larger mass than liquid water.

**C** Four electrons from each oxygen are involved in forming hydrogen bonds.

**D** Each oxygen atom in a water molecule is tetrahedrally bonded to 4 hydrogen atoms.

**Ans: B**

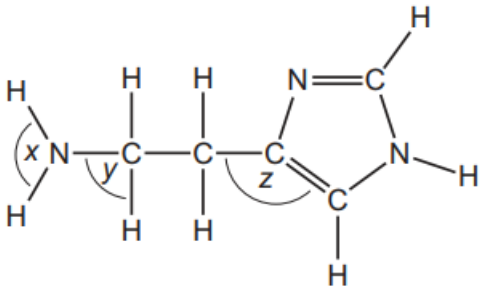
Option A is correct as the open structure (owing to the hydrogen bonds between water molecules) results in a larger volume occupied than liquid water and hence, density of ice is smaller than water.

Option B is incorrect as the open structure does not change the mass.

Option C is correct as each O atom will use its 2 lone pairs of electrons to form 2 hydrogen bonds in ice.

Option D is correct as around each O atom, there are 2 covalent bonds to H atoms and 2 hydrogen bonds to H atoms, resulting in a tetrahedral arrangement.

**6** The structure of histamine is as shown.




histamine

Which is the correct order of bond angle from smallest to largest?

| | Smallest bond angle ⟶ | | Largest bond angle |
|---|---|---|---|
| **A** | x | y | z |
| **B** | z | y | x |
| **C** | y | z | x |
| **D** | x | z | y |

**Ans: A**

x = 107°, y = 109.5°, z = 120°

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

Copper metal, copper(II) ions and water are formed when dilute sulfuric acid is added to copper(I) oxide.

Which option is correct?

| | number of moles of $Cu^{+}$ reacted | number of moles of Cu formed | number of moles of $Cu^{2+}$ formed |
|---|---|---|---|
| **A** | 1 | 1 | 1 |
| **B** | 1 | 2 | 1 |
| **C** | 2 | 1 | 1 |
| **D** | 2 | 2 | 1 |

**Ans: C**

$Cu_2O + H_2SO_4 \rightarrow H_2O + SO_4^{2-} + Cu + Cu^{2+}$

To get 1 mol of Cu and 1 mol of $Cu^{2+}$, refer to Data Booklet for the following half equations.

$Cu^+ + e^- \rightarrow Cu$ --- (1)

$Cu^+ \rightarrow Cu^{2+} + e^-$ -- (2)

(1) + (2): $2Cu^+ \rightarrow Cu + Cu^{2+}$ ($2Cu^+$ came from 1 mol of $Cu_2O$)

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

Which statement is correct?

**A** 2.00g of hydrogen gas contains $3.00 \times 10^{23}$ atoms.

**B** 4.00g of helium gas contains $6.00 \times 10^{23}$ molecules.

**C** 28.0g of carbon monoxide gas contains $6.00 \times 10^{23}$ molecules.

**D** 88.0g of carbon dioxide gas contains $2.40 \times 10^{24}$ atoms.

**Ans: C**

Option A is wrong because 1 mol of $H_2$ contains $6.02 \times 10^{23} \times 2 = 1.204 \times 10^{24}$ atoms.

Option B is wrong because 1 mol of He contains $6.02 \times 10^{23}$ atoms. He is a noble gas and does not exist as molecules.

Option C is correct because 1 mol of CO contains $6.02 \times 10^{23}$ molecules.

Option D is wrong because 2 mol of $CO_2$ contains $2 \times 3 \times 6.02 \times 10^{23} = 3.612 \times 10^{24}$ atoms.

**9** Which compound has the same empirical formula as its molecular formula?

**A** dinitrogen tetraoxide

**B** ethanoic acid

**C** propanone

**D** tetrafluoroethene

**Ans: C**

| | Molecular formula | Empirical formula |
|---|---|---|
| Option A is wrong. | $N_2O_4$ | $NO_2$ |
| Option B is wrong. | $C_2H_4O_2$ | $CH_2O$ |
| Option C is correct. | $C_3H_6O$ | $C_3H_6O$ |
| Option D is wrong. | $C_2F_4$ | $CF_2$ |

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

Which compound contains 54.1% by mass of calcium?

**A** Calcium oxide

**B** Calcium nitrate

**C** Calcium sulfate

**D** Calcium hydroxide

**Ans: D**

For 1 mol of compound;

| | % by mass of Ca |
|---|---|
| CaO | 40.1/56.1 x 100% = 71.5% |
| $Ca(NO_3)_2$ | 40.1/164.1 x 100% = 24.4% |
| $CaSO_4$ | 40.1/136.2 x 100% = 29.4% |
| $Ca(OH)_2$ | 40.1/74.1 x 100% = 54.1% |

**11** 10.0 $cm^3$ of 0.30 mol $dm^{-3}$ thallium nitrate, $TlNO_3$, required 20.00 $cm^3$ of 0.10 mol $dm^{-3}$ acidified $NH_4VO_3$ for oxidation to $Tl^{3+}$. Vanadium is the only element which is reduced.

What is the final oxidation state of vanadium?

**A** 0

**B** +2

**C** +3

**D** +4

**Ans: B**

$Tl^+ \rightarrow Tl^{3+} + 2e^-$

Amount of $Tl^+$ = 0.01 x 0.3 = 0.003 mol

Amount of $e^-$ = 0.003 x 2 = 0.006 mol

Amount of $VO_3^-$ = 0.02 x 0.1 = 0.002 mol

$e^-$ : $VO_3^-$ = 3 : 1

Final oxidation state of vanadium = + 5 – 3 = + 2

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

In an energetics experiment, 2.00 g of a fuel is completely burnt. 55% of the energy released is absorbed by 200 g of water and the temperature rose from 18 °C to 66 °C.

What is the energy released per gram of fuel burnt?

**A** 20 064 J **B** 36 480 J **C** 36 845 J **D** 72 960 J

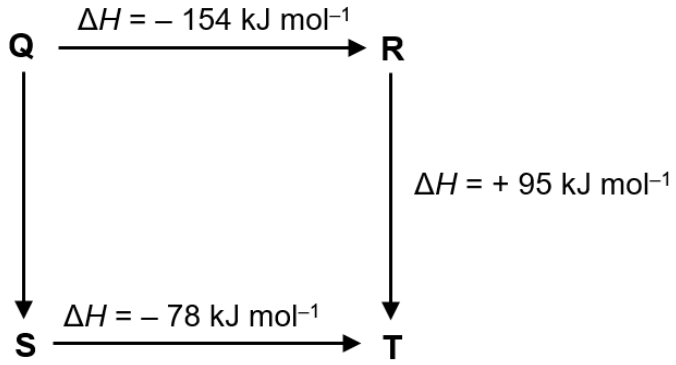
**Ans: B**

q = 200 x 4.18 x (66 – 18) = 40 128 J

q (100%) = (100 x 40 128) / 55 = 72 960 J

Total energy released per gram of fuel burnt = 72 960 / 2 = 36 480 J

**13** The following diagram illustrates the enthalpy changes for a set of reactions.




Which statements are correct?

1 Δ*H* for the conversion of **S** to **R** is + 17 kJ mol$^{-1}$

2 Δ*H* for the conversion of **Q** to **S** is + 19 kJ mol$^{-1}$.

3 The energy level of **T** is lower than the energy level of **Q**.

**A** 1, 2 and 3

**B** 1 and 2 only

**C** 2 and 3 only

**D** 2 only

**Ans: C**

Option 1 is wrong as Δ*H* should be – 78 – 95 = – 173 kJ mol$^{-1}$.

Option 2 is correct as Δ*H* should be – 154 + 95 + 78 = + 19 kJ mol$^{-1}$.

Option 3 is correct as Δ*H* should be – 154 + 95 = – 59 kJ mol$^{-1}$, which means that **T** has a lower energy level than **Q**.

**14** Cs-137 is a radioactive isotope with a half-life of 30 years. It was reported that about 9.6 kg of Cs-137 was released into the sea following the Japan nuclear disaster in 2011. What is the mass of Cs-137 left in the sea after 150 years?

**A** 0.30 kg

**B** 0.60 kg

**C** 1.92 kg

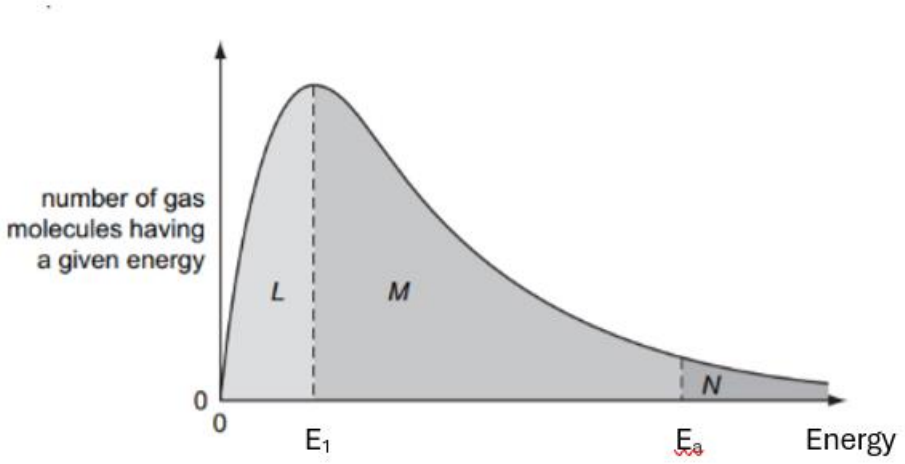
**D** 3.84 kg

**Ans: A**

$$\left(\frac{1}{2}\right)^{\left(\frac{150}{30}\right)} = \frac{mass}{9.6}$$

$$mass = 9.6\ X\ \left(\frac{1}{2}\right)^{\left(\frac{150}{30}\right)} = 0.30\ kg$$

**15** The Boltzmann distribution shows the number of molecules having a particular energy at constant temperature.




**L** refers to the area under the curve from 0 to $E_1$.

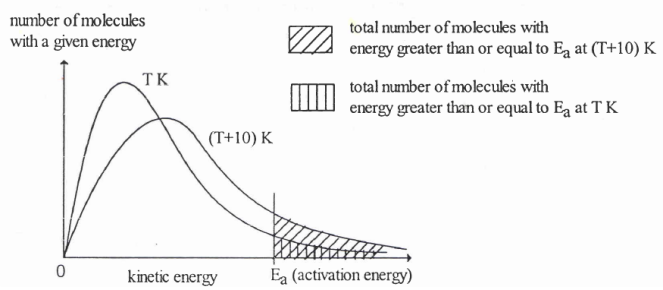
**M** refers to the area under the curve from $E_1$ to $E_a$.

**N** refers to the area after $E_a$.

If the temperature is increased by 10 °C, what happens to the size of the areas labelled **L**, **M** and **N**?

| | **L** | **M** | **N** |
|---|---|---|---|
| **A** | increase | decrease | decrease |
| **B** | decrease | increase | increase |
| **C** | decrease | decrease | increase |
| **D** | increase | increase | decrease |

**Ans: B**




According to the graph at higher T, **L** should decrease while **M** and **N** should increase.

**16** 1.00 mol of $N_2O_4$ and 0.200 mol of $NO_2$ were added to a sealed vessel of fixed volume of 2.00 $dm^3$ at 298 K. When the system reached equilibrium, 0.680 mol of $NO_2$ was present in the vessel.

$$N_2O_4(g) \rightleftharpoons 2NO_2(g)$$

Which statements are true about this equilibrium?

1 0.760 mol of $N_2O_4$ are present at equilibrium.
2 The value for the equilibrium constant, $K_c$, is 0.608.
3 The pressure in the vessel at equilibrium is lower than the pressure in the vessel before the reaction started.

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

**Ans: D**

| | $N_2O_4(g)$ | $\rightleftharpoons$ | $2NO_2(g)$ |
|---|---|---|---|
| Initial / mol | 1.00 | | 0.200 |
| Change / mol | -0.240 | | +0.480 |
| Eqm / mol | 0.760 | | 0.680 |

$K_c = (0.680/2)^2 / (0.760/2) = 0.304$
Statement 1 is correct.
Statement 2 is wrong.
Since $n_{total}$ is greater at eqm, pressure should be higher. Statement 3 is wrong.

**17** What is true about an equilibrium system whose $K_c$ is independent of temperature?

**A** The number of moles of gaseous particles on both sides are equal.
**B** The system is a homogenous equilibrium system.
**C** The enthalpy change of the reaction is 0 kJ $mol^{-1}$.
**D** Its $K_c$ has no units.

**Ans: C**

When $K_c$ doesn't change with temperature, that is possible when there is no shift in equilibrium position due to temperature changes. Thus enthalpy change must be 0 kJ $mol^{-1}$.

**18** Which reaction involves both Arrhenius acid and Arrhenius base?

**A** $HCl\ (g) + NH_3\ (g) \rightarrow NH_4Cl\ (s)$

**B** $2HCl\ (aq) + Zn\ (s) \rightarrow ZnCl_2\ (s) + H_2\ (g)$

**C** $HNO_3\ (aq) + CaCO_3\ (s) \rightarrow Ca(NO_3)_2\ (aq) + CO_2\ (g) + H_2O\ (l)$

**D** $2HNO_3\ (aq) + Ca(OH)_2\ (aq) \rightarrow Ca(NO_3)_2\ (aq) + 2H_2O\ (l)$

**Ans: D**

A: $HCl\ (g) + NH_3\ (g) \rightarrow NH_4Cl\ (s)$

$NH_3$ is not an Arrhenius base as it does not dissociate to produce $OH^-$ in solution.

B: $2HCl\ (aq) + Zn\ (s) \rightarrow ZnCl_2\ (s) + H_2\ (g)$

This is a redox reaction as Zn is oxidized since its oxidation state increases from 0 in Zn to +2 in $Zn^{2+}$ and H in $HCl$ is reduced as its oxidation state decreases from +1 in $HCl$ to 0 in $H_2$. It does not involve an Arrhenius acid and base behavior.

C: $HNO_3\ (aq) + CaCO_3\ (s) \rightarrow Ca(NO_3)_2\ (aq) + CO_2\ (g) + H_2O\ (l)$

$CaCO_3$ is not an Arrhenius base as it does not dissociate to produce $OH^-$ in solution.

D: $2HNO_3\ (aq) + Ca(OH)_2\ (aq) \rightarrow Ca(NO_3)_2\ (aq) + 2H_2O\ (l)$

$Ca(OH)_2$ is an Arrhenius base as it is a substance that produces $OH^-$ in solution.

$HNO_3$ is an Arrhenius acid as it is a substance that produces $H^+$ in solution.

**19** What is the final pH of a solution formed by mixing equal volumes of aqueous hydrochloric acid at pH 1.0 and at pH 2.0?

**A** 0.96 **B** 1.26 **C** 1.50 **D** 3.00

**Ans: B**

At pH 1.0, $[H^+] = 10^{-1}$

At pH 2.0, $[H^+] = 10^{-2}$

Since equal volumes are mixed, concentration of $H^+$ will be halved.

Total $[H^+] = 10^{-1}/2 + 10^{-2}/2 = 0.055$ mol $dm^{-3}$

pH = - lg (0.055) = **1.26**

**20** The oxide of element **Z** has a giant structure. The chloride of **Z** reacts with water to give a solution with a pH less than 5. Which pairs shows two elements which could be **Z**?

**A** Aluminium, Phosphorus

**B** Aluminium, Silicon

**C** Phosphorus, Sodium

**D** Sodium, Silicon

**Ans: B**

| Element | Structure of oxide | pH of chloride |
|---|---|---|
| Sodium | Giant ionic lattice | 7 |
| Aluminium | Giant ionic lattice | 3 |
| Silicon | Giant molecular | 2 |
| Phosphorus | Simple molecular | 2 |

**21** Which property increases steadily down Group 1 elements?

**A** Melting point

**B** Electronegativity

**C** Charge density

**D** Reducing power

**Ans: D**

Down the group, the Group 1 elements undergo oxidation more readily as their valence electrons are less attracted. Hence, their reducing power increases.

**22** Which statement best explains the trend of volatility of hydrogen halides from HC*l* to HI?

**A** Covalent bonds between atoms become stronger.

**B** Electron cloud size of the molecules increases.

**C** Permanent dipole – permanent dipole (pd-pd) interactions become weaker.

**D** Instantaneous dipole – induced dipole (id-id) interactions become stronger.

**Ans: D**

HC*l* to HI exists as simple covalent molecules with pd-pd and id-id between molecules. However, going from HC*l* to HI, the volatility decreases and the bp increases. This is due to the increasing strength of id-id due to the increasing size of the electron cloud as the pd-pd actually becomes weaker due to decreasing polarity from HC*l* to HI.

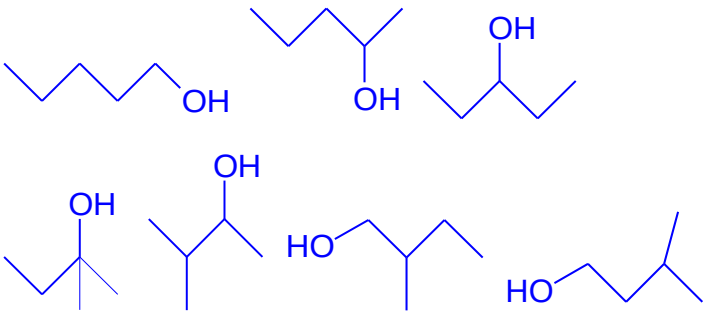
**23** How many saturated constitutional (structural) isomers are there with the formula of $C_5H_{12}O$ are alcohols?

**A** 5

**B** 6

**C** 7

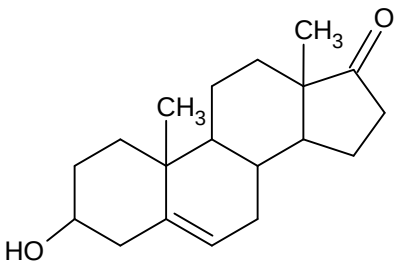
**D** 8




Total: 7

Ans: C

**24** Androstenolone, $C_{19}H_{28}O_2$, is a steroid secreted by the adrenal cortex.




Androstenolone

When it is heated with hydrogen gas and nickel catalyst, it forms compound **Z**.

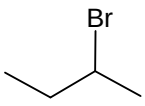
Which row identifies the number of cis-trans isomers in Androstenolone and the molecular formula of **Z?**

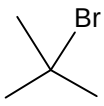
| | number of cis-trans isomers | molecular formula of **Z** |
|---|---|---|
| **A** | 2 | $C_{19}H_{30}O_2$ |
| **B** | 0 | $C_{19}H_{30}O_2$ |
| **C** | 2 | $C_{19}H_{32}O_2$ |
| **D** | 0 | $C_{19}H_{32}O_2$ |

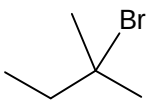
**Ans: D**

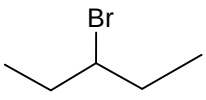
There are no cis-trans isomers in Androstenolone.
Both the ketone group and the alkene will react with $H_2$ (g) with Ni catalyst, heat to undergo reduction. Hence, 2 moles of $H_2$ will be added to the ketone and alkene reaction.
Thus, the molecular formula of **Z** is $C_{19}H_{32}O_2$

**25** Which halogenoalkane gives the greatest number of different alkenes (including stereoisomers) on elimination?

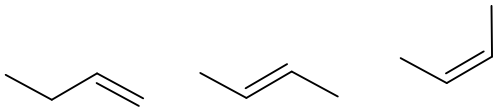
**A** 

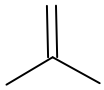

**B** 

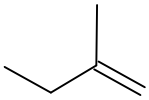
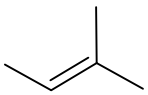

**C** 

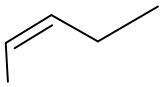
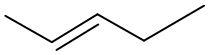

**D** 


**Ans: A**

Product of A: 

Product of B: 

Products of C:  

Products of D:  

Alkene A gives a total of 3 alkenes on elimination.

Both Alkene B and D gives only 1 alkene on elimination. However, the product of D exhibit cis-trans isomerism. Hence, A is the best answer.

**26** Ethyl acetate is a widely used solvent for paints and perfumes and has a sweet and fruity odor. It has the molecular formula of $C_4H_8O_2$.

After heating under reflux with dilute sulfuric acid, it forms **P** ($C_2H_4O_2$) and **Q** ($C_2H_6O$).

What is the structure formula of ethyl acetate?

**A** $CH_3COCH_2CHO$

**B** $CH_3CH_2OCOCH_3$

**C** $CH_3CH_2CH_2COOH$

**D** $CH_3CH_2COOCH_3$

**Ans: B**

Ethyl acetate is an ester. Hence, it will undergo acidic hydrolysis with dilute sulfuric acid, heat under reflux to form a carboxylic acid (P) and an alcohol (Q).

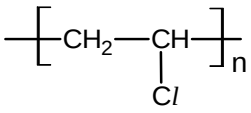
Structure of P: $CH_3COOH$

Structure of Q: $CH_3CH_2OH$

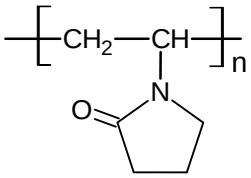
Hence, structural formula of ethyl acetate is $CH_3COOCH_2CH_3$.

**27** Which polymer is used in waterproof fabrics for mattresses and outdoor furniture?

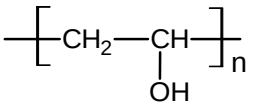
**A**



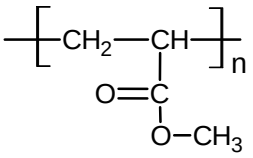
**B**



**C**



**D**



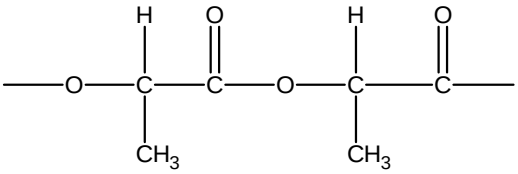
**Ans: A**

Options B, C and D are all wrong as they can form hydrogen bonding with water, hence, these are water-soluble polymers.

Option A is PVC, polyvinylchloride. It is unable to form hydrogen bonding with water, hence, are water-resistant.

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

A short section of the polymer, poly(lactic acid), is shown.



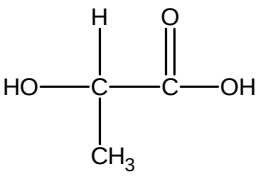
The relative molecular mass of poly(lactic acid) is approximately 240 000.

How many monomers are present in poly(lactic acid)?

**A** 1000 **B** 1600 **C** 2600 **D** 3300

**Ans: D**

Monomer of poly(lactic acid):



$M_r$ of monomer of poly(lactic acid) that makes up the polymer

= (3 x 12.0 + 16.0 x 3 + 6.0) – 18.0 = 72.0

No of monomers = 240 000 / 72 = 3333 (approximately 3300 monomers)

**29** In recent times, silver nanoparticles were widely utilised as catalyst in a diverse range of organic reactions. However, it was found that presence of sulfur in the reaction mixture will reduce the catalytic efficiency of silver nanoparticles.

Which statement about silver nanoparticles is **incorrect**?

**A** The efficiency of silver nanoparticles as a catalyst is greatly improved due to its large surface area to volume ratio.

**B** Sulfur poisons the catalyst by coating the surface of the silver nanoparticles, preventing the metal from coming into contact with the reactants.

**C** Silver nanoparticles can be easily inhaled and become a potential health hazard.

**D** Silver nanoparticles are particles with all dimensions between 1 to 10 nm.

**Ans: D**

Nanoparticles are particles with all dimensions between 1 to 100 nm on the nanoscale.

**30** A gecko can climb vertical walls and hang from the ceiling with its feet above its head.

Recent research has resulted in the invention of “gecko tape”, a reusable adhesive that has a structure which is similar to the feet of geckos. This gecko tape can stay sticky even under extreme temperatures.

Which features likely enable the tape to stick to a surface in a similar way to that of how a gecko hangs on the ceiling?

1 The surface of the tape possesses many finely divided nanostructures.

2 The tape has a large surface area of contact with any surface.

3 Hydrogen bonds exist between the tape and the surface.

**A** 1, 2 and 3

**B** 1 and 2 only

**C** 1 and 3 only

**D** 2 and 3 only

**Ans: B**

Like the structure of gecko feet, the surface of the tape is likely to have many finely divided nanostructures possessing high surface area to volume ratio, creating a huge collective

surface area of contact with a surface. Thus, the cumulative instantaneous dipole - induced dipole between the nanostructures and surface translates into enormous attractive forces of attraction.

Hence, statement (1) and (2) are correct. However, for statement (3), it is the ability to form **cumulative** instantaneous dipole-induced dipole that translates into enormous attractive forces of attraction and not hydrogen bonds.

**END OF PAPER**