



ST ANDREW'S JUNIOR COLLEGE

JC2 Preliminary Examinations

Higher 2

CANDIDATE
NAME

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CLASS

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CHEMISTRY

9729/01

Paper 1 Multiple Choice

16 September 2021

1 hour

Additional Materials: Multiple Choice Answer Sheet
Data Booklet

READ THESE INSTRUCTIONS FIRST

Write in soft pencil.

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

Write your name and class on the Answer Sheet in the spaces provided.

There are **thirty** questions on this paper. Answer **all** questions. For each question there are four possible answers **A, B, C** and **D**.

Choose the **one** you consider correct and record your choice in **soft pencil** on the separate Answer sheet.

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.

- 1 Which of the following contains the same number of particles as 16 g of oxygen atoms?

A The number of molecules in 24 dm³ of Cl₂ under room conditions

B The number of ions in 1 dm³ of 1 mol dm⁻³ aqueous HCl

C The number of atoms in 111.6 g of Fe

D The number of formula units of 29.25 g of NaCl

Ans: A

$$L = 6.02 \times 10^{23} \text{ mol}^{-1}$$

$$\text{No. of atoms} = 16/32 \times 2 \times L = 1L \text{ molecules}$$

$$\text{A - No. of molecules} = 24/24 \times 1 \times L = L \text{ molecules}$$

$$\text{B - No. of ions} = 1 \times 1 \times 2 = 2L \text{ ions}$$

$$\text{C - No. of atoms} = 111.6/55.8 \times L = 2L \text{ atoms}$$

$$\text{D - No. of formula unit} = 29.25/58.5 \times L = 0.5 L \text{ formula unit}$$

- 2 The first eight ionisation energies of an element Q (in kJ mol⁻¹) are as follows:

966, 1950, 2730, 4850, 6020, 12300, 15400, 18900

Which of the following statements about element Q is correct?

A It can form a basic oxide.

B It can form a chloride with the formula QCl₅.

C It has an even number of protons in its atom.

D It can form a chloride that is trigonal planar in shape.

Ans: B

The increase between the fifth and sixth IE is the largest. Hence, there is 5 valence electrons. Hence, the formula is QCl₅.

- 3 A 2.0 g sample containing 0.0130 mol of organoboron compound, with the formula C_xH_yBO_z, was burnt in an excess of oxygen. 4.58 g of CO₂ and 1.76 g of H₂O were produced. What is the molecular formula of the organoboron compound?

A CH₂BO₂

B C₈H₇BO₂

C C₈H₁₅BO₂

D C₉H₁₅BO

Ans: C

$$\text{No. of moles of carbon in sample} = 4.58/44 = 0.104$$

$$\text{No. of moles of H in sample} = 1.76/18 \times 2 = 0.196$$

$$\text{Value of } x = 0.104/0.0130 = 8$$

$$\text{Value of } y = 0.196/0.0130 = 15$$

$$M_r \text{ of sample} = 2/0.0130 = 154$$

$$\text{Value of } z = (154 - 96 - 15 - 10.8)/16 = 2$$

Molecular formula is $\text{C}_8\text{H}_{15}\text{BO}_2$.

- 4 Beams of charged particles travelling at the same speed from different sources are subjected to an electric field in two different experiments.

In the first experiment, protons are deflected by an angle of $+12^\circ$. In another experiment under identical conditions, particle **X** is deflected by an angle of -4° .

What could be the composition of particle **X**?

	protons	neutrons	electrons
A	1	2	1
B	3	3	5
C	4	5	1
D	4	5	5

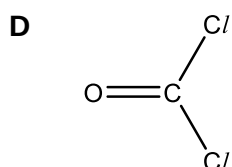
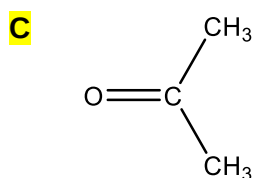
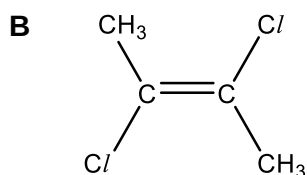
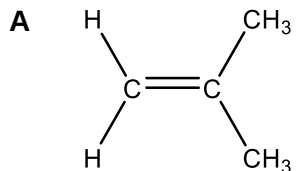
Ans: B

For proton, charge/mass ratio = $+1/1 \rightarrow +12^\circ$

Since particle X has angle of deflection -4° ,

its charge/mass ratio should be $-2/6 = -1/3$

- 5 Which molecule has the largest overall dipole moment?



Ans: C

Option A and B have overall net dipole of zero or close to zero

Option D has a net dipole moment but smaller than that of option C.

6 Which statements about the lattice structure of the crystalline solid of diamond and ice are correct?

- 1 The hybridisation of the oxygen atom in ice and the carbon atom in diamond are the same.
- 2 The H-O-H bond angle is 105° while the C-C-C bond angle is 109.5° .
- 3 The lattice structure are held by strong covalent bonds only.

A 1, 2 and 3

B 2 and 3 only

C 1 only

D 2 only

Ans: C

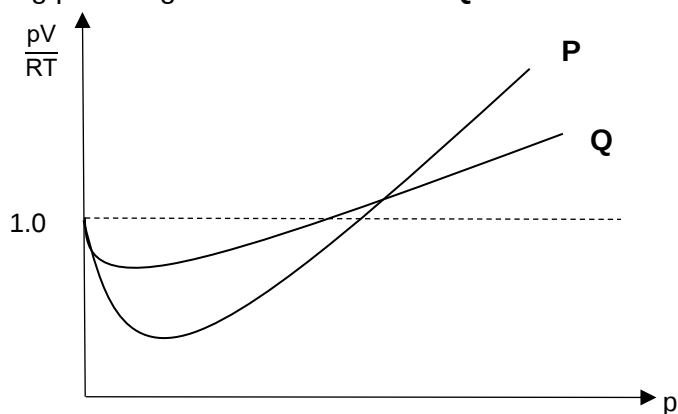
Option 1. The hybridisation of the oxygen atom in ice and the carbon atom in diamond are sp^3

Option 2. Both are tetrahedral and hence 109.5° .

Option 3. Ice is held by hydrogen bonding and covalent bond.

7 The value of $\frac{pV}{RT}$ is plotted against p for one mole of each of the two gases, **P** and **Q**, where p is the pressure, V is the volume and T is the temperature of the gas.

Which of the following pairs of gases could be **P** and **Q**?



P

Q

A

N_2

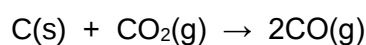
O_2

B	CH ₄	CH ₃ Cl
C	HCl	HF
D	HBr	F ₂

Ans: D

HBr is polar, with stronger pd-pd and id-id while F₂ is non-polar with id-id only, hence HBr deviates more from ideal gas behaviour.

- 8 The following reaction is thermodynamically feasible only at high temperature.



Which row correctly describes the signs of ΔH and ΔS for the reaction?

	ΔH	ΔS
A	–	–
B	–	+
C	+	–
D	+	+

Ans: D

$$\Delta G = \Delta H - T\Delta S$$

ΔS must be positive since there are more moles of gases produced. Since the reaction is thermodynamically feasible only at high temperature, ΔH must be positive.

- 9 Some ΔH_c values are given below.

Element	$\Delta H_c / \text{kJ mol}^{-1}$
H ₂	–285
C	–394

What is the ratio of heat generated by hydrogen to that of carbon if the same mass of each substance is burned?

A	0.7	B	1.4	C	3.4	D	4.3
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Ans: D

Let x be the mass burned.

Heat generated from x g of H₂ = $285x/2 = 142.5x$

Heat generated from x g of C = $394x/12 = 32.8$

Ratio = $142.5/32.8 = 4.3$

- 10** Some information about some of the elements of Period 5 of the Periodic Table is shown.

element	Rb	Sr	In	Sn	Sb	Te	I	Xe
Electrical conductivity	high	high	high	high	high	Semi-conductor	zero	zero
Boiling point/ K	961	1650	2300	2540	1650	1260	457	165

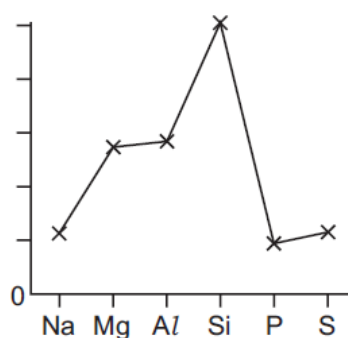
Which statement about these elements is correct?

- A** Te exists as a giant metallic structure with electrostatic forces of attraction.
B TeI_2 exists as an ionic compound with strong electrostatic forces of attraction.
C There are more elements with metallic structures in Period 5 than in Period 3.
D Those elements in Period 5 which have a boiling point under 1000 K exist as simple molecules.

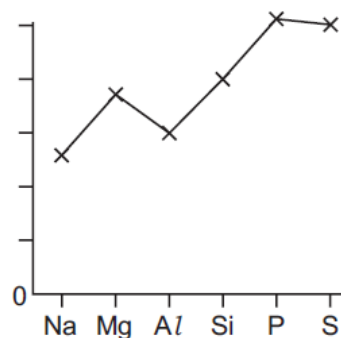
Ans: C

- B** A: Te has a giant covalent structure with strong covalent bonds
M B: TeI_2 exists as a covalent compound as both Te and I are non metals.
 D: Rb is a metallic structure

- 11** The trends in two physical properties of the elements Na, Mg, Al, Si, P and S are shown in the following graphs.



Graph 1



Graph 2

Which of the following illustrates the correct physical property for the corresponding graphs above?

	Graph 1	Graph 2
A	melting point	electrical conductivity
B	1 st ionisation energy	electrical conductivity
C	melting point	1 st ionisation energy
D	1 st ionisation energy	melting point

Ans: C

Graph 1: The melting point increases from Na to Al as the metallic bonding is stronger. Si has the highest melting point as it is a giant covalent lattice which requires the largest amount of energy to overcome the strong network of Si-Si bond. S₈ and P₄ are simple covalent molecule. As the number of electrons for S₈ increases, the id-id increases, hence, the melting point increases.

Graph 2: Across the period, nuclear charge increases while the increase in shielding effect is insignificant as electrons are added to the same shell. The effective nuclear charge increases, hence, the 1st ionisation energy increases. However, the first ionisation energy for Al is lower than expected because less energy is needed to remove the 3p electron which is further away from nucleus and experience additional shielding from 3s electrons.

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

Which of the following statements is correct for Group 2 elements and its compounds?

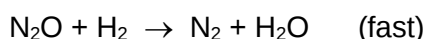
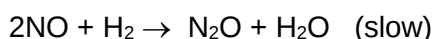
- A Magnesium is kept in oil as it is more reactive while barium is kept in the open.
- B Barium reacts with chlorine more spontaneously than magnesium as it has a higher reducing power.**
- C The rate of decomposition is slower for strontium carbonate than barium carbonate.
- D The volume of CO₂ produced is the same when the same mass of strontium carbonate and barium carbonate are decomposed.

Ans: B

The reducing power of Group 2 elements increases. Hence, Ba reduces chlorine more spontaneously than Mg ($E^\ominus_{\text{cell}}$ is more positive $\rightarrow \Delta G^\ominus$ is more negative). Hence, Ba is kept in oil instead of Mg as Ba is more reactive. (Option A is incorrect while Option B is correct).

The rate of decomposition is faster for strontium carbonate as Sr^{2+} has a higher charge density as its ionic radius is smaller than Ba^{2+} . Hence, it has greater polarising power to weaken the C-O bond in the CO_3^{2-} ion. However, if the same mass of BaCO_3 and SrCO_3 is used, as the M_r of BaCO_3 is greater, the number of moles of BaCO_3 will be smaller so that number of moles of CO_2 produced is less, so lesser volume. (Option C and D are incorrect).

- 13 The reaction of nitrogen oxide and hydrogen involves the following steps:



Which of the following statements is **incorrect** based on the information above?

- A A redox reaction occurs in the slow step.
- B It is a second order reaction with respect to $[\text{NO}]$.
- C The units of the rate constant is $\text{mol}^{-3} \text{dm}^9 \text{s}^{-1}$.**
- D N_2O is not present in the overall equation.

Ans: C

Option A – correct. The N decreases its oxidation state from +2 in NO to +1 in N_2O in the slow step while H in H_2 increases its oxidation state from 0 in H_2 to +1 in water. Hence, a redox reaction occur in the slow step.

Option B – correct. Following the slow step, rate = $k[\text{NO}]^2[\text{H}_2]$

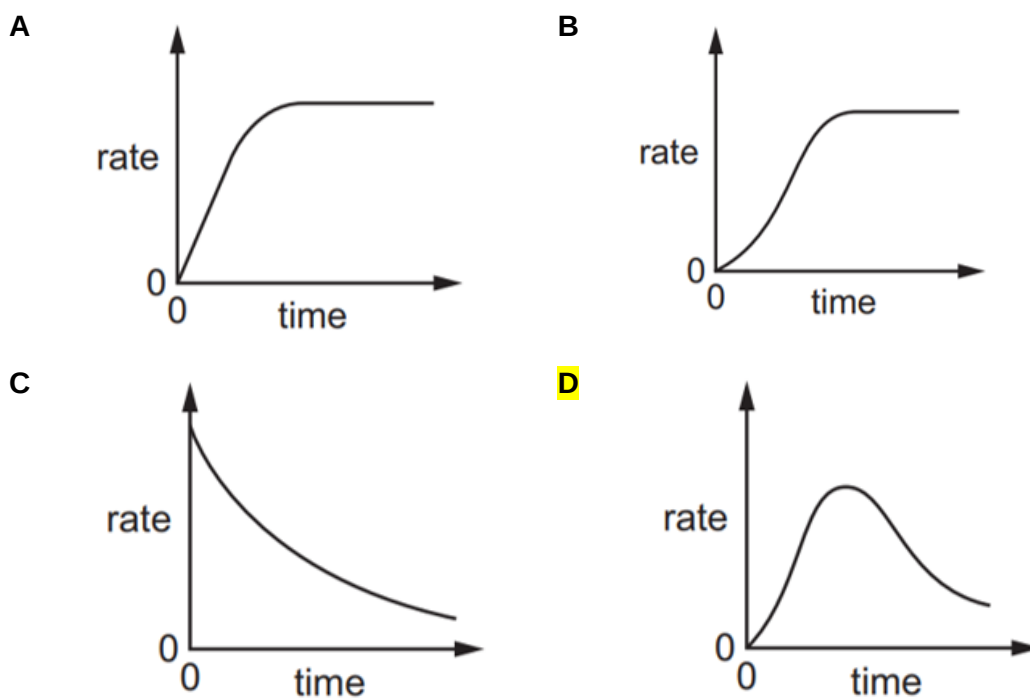
Option C – incorrect. Following the slow step, rate = $k[\text{NO}]^2[\text{H}_2]$

Hence units of k should be $\text{mol}^{-2} \text{dm}^6 \text{s}^{-1}$

Option D – N_2O is the intermediate and would be cancelled out and hence, would not appear in the overall equation.

- 14 An autocatalytic reaction is a reaction in which one of the products catalyses the reaction.

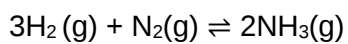
Which curve would be obtained if the rate of an autocatalytic reaction is plotted against time?



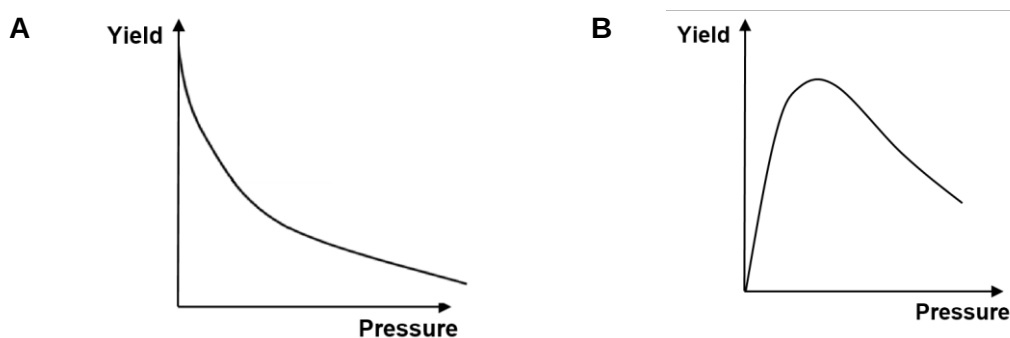
Ans: D

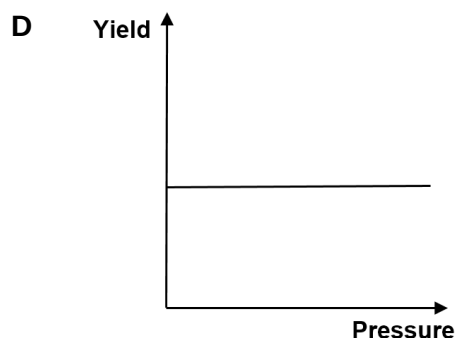
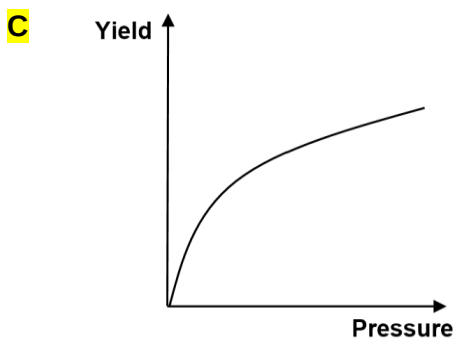
Rate increases at the beginning due to production of catalyst, but decreases as concentration of reactants decrease as reaction progresses.

- 15** Ammonia can be synthesised directly using a mixture of hydrogen gas and nitrogen gas in a reversible reaction as shown:



Which one of the following describes the change in yield of ammonia at equilibrium as pressure increases?





Ans: C

When pressure increases, POE shifts to RHS to favour less number of moles of NH_3 to remove the pressure. Hence, the yield increases.

16 Which of the following mixtures are Brønsted-Lowry acid and its conjugate base pair?

- 1 H_2O and OH^-
- 2 H_2PO_4^- and HPO_4^{2-}
- 3 NaH and Na

A 1, 2 and 3 only

B 1 and 2 only

C 2 and 3 only

D 2 only

Ans: B

A Brønsted Lowry acid, HA is a proton donor. It donates its proton to be a conjugate base A^- .

Hence,

Option 1: correct

Option 2: correct

Option 3: not an acid-base reaction since oxidation number of Na decrease from +1 to 0.

17 Solutions **E**, **F**, **G** and **H** contain a strong monobasic acid, a weak monobasic acid **HX**, a strong base and a salt of **HX**, but not necessarily in the same order. The concentration and pH at 25 °C for each solution are shown below.

Solution	Concentration /mol dm ⁻³	pH
E	1.0	4.0

F	1.0	9.4
G	0.01	12.0
H	0.01	2.0

Which one of the following produces an acidic buffer?

A Mixing 10 cm³ of **E** and 50 cm³ of **G**

B Mixing 10 cm³ of **E** and 50 cm³ of **H**

C Mixing 10 cm³ of **F** and 1 dm³ of **H**

D Mixing 10 cm³ of **F** and 1 dm³ of **G**

Ans: A

A buffer is made up of a weak acid/ basic salt or weak base/ acidic salt

Solution	Concentration /mol dm ⁻³	pH	Type
E	1.0	4.0	Weak acid
F	1.0	9.4	Weak base
G	0.01	12.0	Strong Base
H	0.01	2.0	Strong Acid

A: Excess weak acid + strong base → weak acid/ basic salt (acidic buffer)

B: Excess weak acid + weak base → weak acid/ salt of weak acid and base (not buffer)

C: Weak base + excess strong acid → strong acid/ acidic salt → acidic solution

D: Weak base + strong base → basic solution

18 How many tertiary alcohols have the molecular formula C₆H₁₄O?

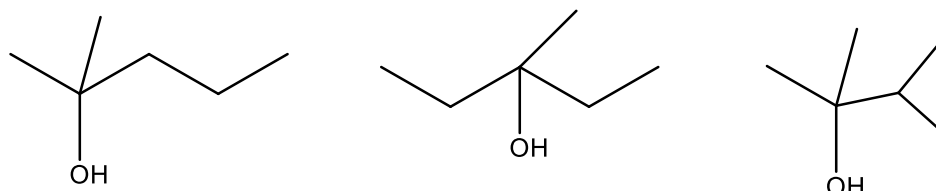
A 1

B 2

C 3

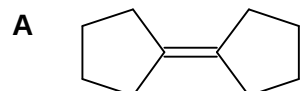
D 4

Ans: C

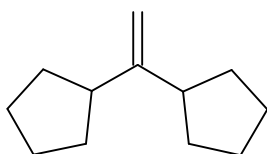


19 Oxidation of an alkene **W** gives a diol; further oxidation gives a diketone.

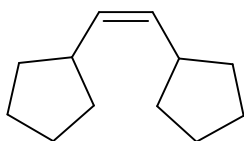
Which one of the following could be **W**?



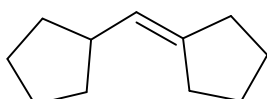
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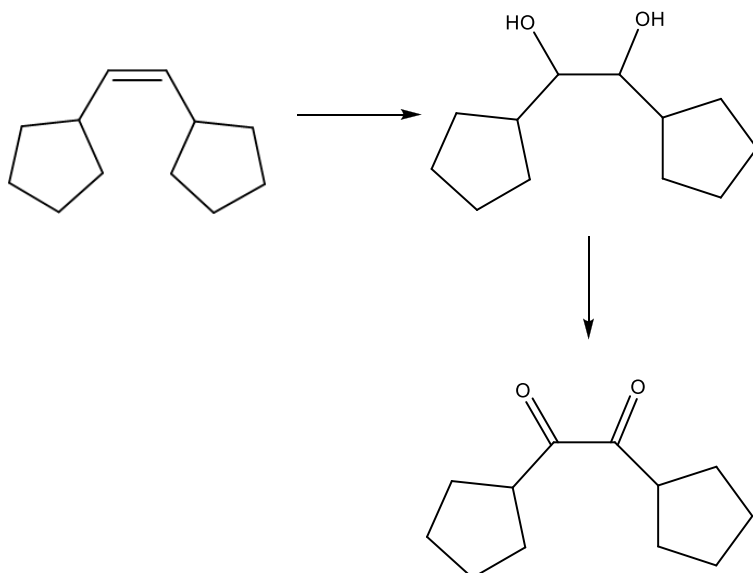
C



D



Ans: C



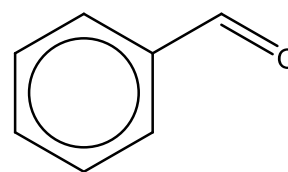
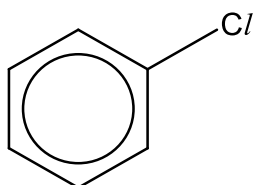
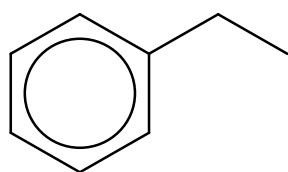
20 Use of the Data Booklet is relevant for this question.

Which of the following temperatures and positions of substitution (relative to the substituent) is most suitable for **E**, **F**, **G** to form mono-nitrated products?

E

F

G



A	> 55°C 2 or 4 - directing	> 55°C 2 or 4 - directing	> 55°C 2 or 4 - directing
B	> 55°C 2 or 4 - directing	> 55°C 3 - directing	> 55°C 2 or 4 - directing
C	< 55°C 2 or 4 - directing	> 55°C 2 or 4 - directing	> 55°C 3 - directing
D	< 55°C 2 or 4 - directing	> 55°C 3 - directing	> 55°C 3 - directing

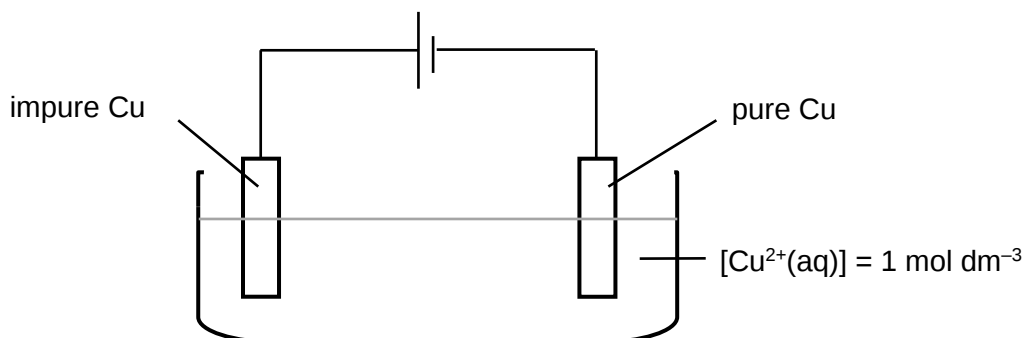
Ans: C

E has an electron-donating –ethyl group that activates the ring, hence less harsh condition is required and it is 2 or 4- directing.

F has an electron-withdrawing –chlorine group which deactivates the ring, hence harsher condition is required but it is 2 or 4-directing.

G has an electron-withdrawing –COH which deactivates the ring, hence harsher condition is required but it is 3-directing

- 21 An electrolytic cell is set up for the purification of a mass of impure copper as shown.



The sample of impure Cu is known to contain nickel and silver as minor impurities.

Which of the following factors, when used in a larger quantity, results in more pure copper deposit on the cathode?

- A** concentration of Cu^{2+} electrolyte
- B** mass of impure Cu
- C** temperature

D current

Ans: D

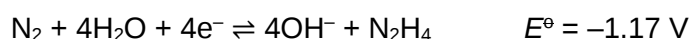
Using the equations $Q=It$

where n = amount of Cu deposited, $z = 2$ for $\text{Cu}^{2+} + 2\text{e}^- \rightarrow \text{Cu}$

The amount of charge supplied will affect the amount of Cu deposited. The amount of charge, Q , is affected by current used and the length of time for which the current is run.

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

Hydrazine (N_2H_4) can be used to reduce metal ions to their elemental forms in the treatment of wastewater. An important half-equation involving hydrazine is shown.



Which of the following ions **cannot** be removed from wastewater by hydrazine?

A Pb^{4+} **B** Co^{3+} **C** Sn^{2+} **D** V^{2+}

Ans: D

If the ions cannot be removed by N_2H_4 implies there is no reaction $\rightarrow E_{\text{cell}} < 0$

$E^\ominus$ of $\text{V}^{2+}/\text{V} = -1.20 \text{ V}$

N_2H_4 will undergo oxidation while the other ions will undergo reduction.

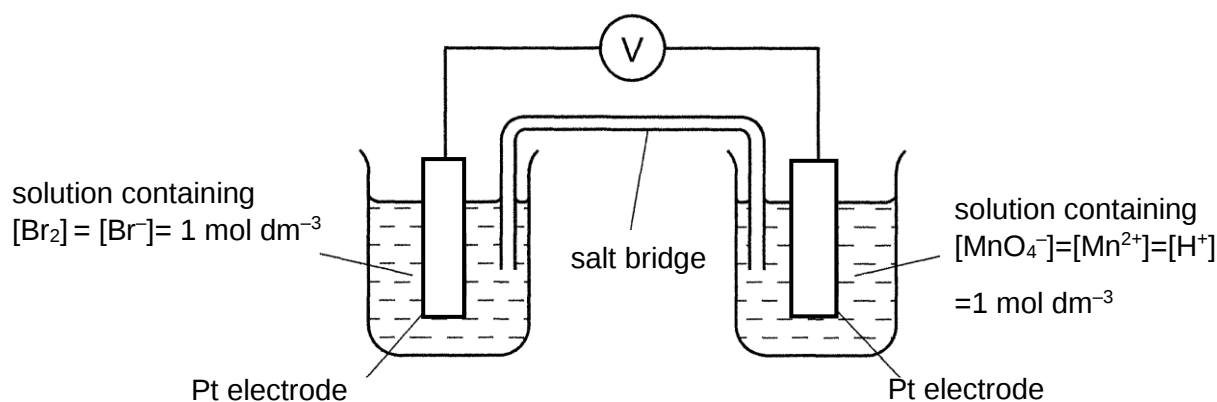
$$E_{\text{cell}} = E_{\text{cathode}} - E_{\text{anode}}$$

$$= -1.2 - (-1.17)$$

$$= -0.03 \text{ V (not feasible)}$$

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

The following electrochemical cell was set up at 25°C



Which of the following statements are true?

- 1 When silver nitrate crystals are added to the Br_2/Br^- half cell, E_{cell} becomes more positive.
- 2 The ΔG° of the above reaction is -434 kJ mol^{-1} .
- 3 Addition of water to the $\text{MnO}_4^-/\text{Mn}^{2+}$ half-cell has no effect on the E_{cell} of the cell.

A 1 only

B 2 only

C 1 and 2 only

D 2 and 3 only

Ans: B

Option 1: False; When silver nitrate crystals are added to the Br_2/Br^- half cell, Ag^+ reacts with Br^-



$[\text{Br}^-]$ decreases, POE shifts right and E_{anode} is more positive. Hence E_{cell} becomes less positive.

Option 2: True; $\Delta G^\circ = -nFE^\circ$, where $n = 10$ electrons transferred

$$\Delta G^\circ = -(10) \times 96500 \times (+0.45)$$

$$= -434 \text{ kJ mol}^{-1} \text{ (3 s.f.)}$$

Option 3: False; Addition of water to the $\text{MnO}_4^-/\text{Mn}^{2+}/\text{H}^+$ will decrease the concentration of all the ions. POE shifts (left) to the side with more ions to increase the concentration, E_{cathode} more negative. E_{cell} more negative.

24 An organic molecule has

- the composition, by mass, C, 40%; H, 6.7%; O, 53.3%,
- the ability to rotate plane polarised light,

What is the smallest number of carbon atoms this molecule can have?

A 1

B

2

C

3

D

4

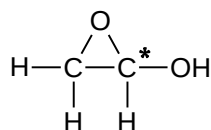
Ans: B

Element	C	H	O
% mass	40	6.7	53.3
Amt	3.33	6.7	3.33
Ratio	1	2	1

Empirical Formula is CH_2O .

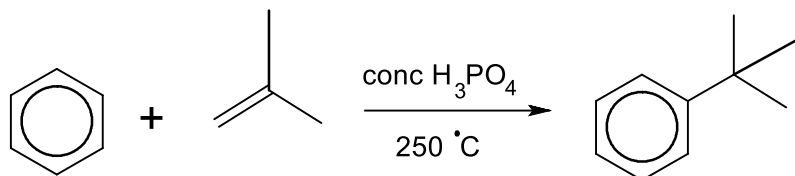
Consider Molecular Formula (MF) in increasing number of carbon atoms.

EF is CH₂O:
MF is C₂H₄O₂:

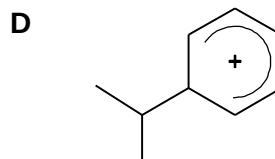
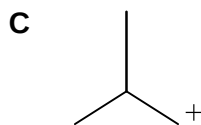
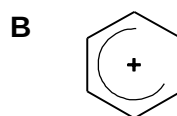
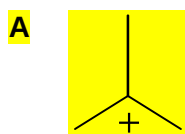


A cyclic structure can give a chiral carbon.

- 25 The following industrial reaction involves benzene and methylpropene.

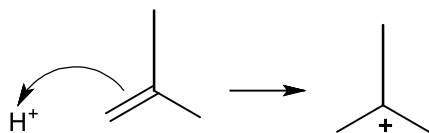


Which of the following intermediate is likely formed in this reaction.



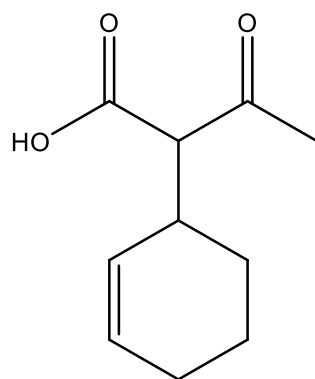
Ans: A

H₃PO₄ is used as a strong acid catalyst in the Electrophilic addition of H₂O to propene.



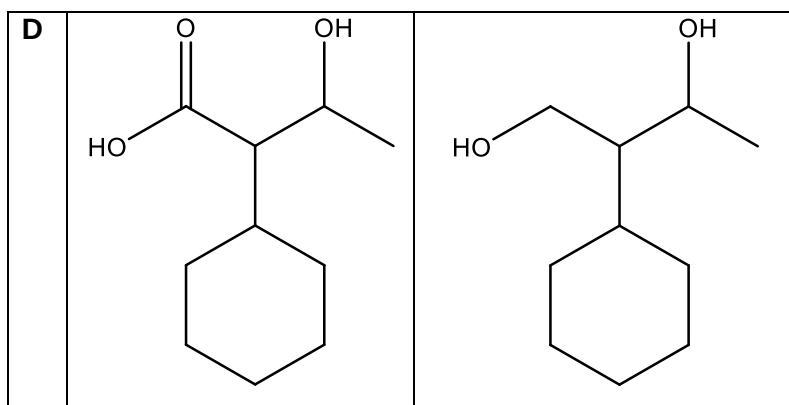
Once the strong electrophile (a carbocation) is formed, it will undergo ES with the benzene.

- 26 Which are the products formed when compound **X** reacts with the following reducing agents?



compound **X**

	H ₂ , Pt	LiAlH ₄ in dry ether
A	<chem>CC(=O)C(C(=O)O)C1=CCCCC1</chem>	<chem>CC(O)C(CO)C1=CCCCC1</chem>
B	<chem>CC(=O)C(C(=O)O)C1=CCCCC1</chem>	<chem>CC(O)C(CO)C1CCCCC1</chem>
C	<chem>CC(=O)C(C(=O)O)C1=CCCCC1</chem>	<chem>CC(O)C(CO)C1=CCCCC1</chem>



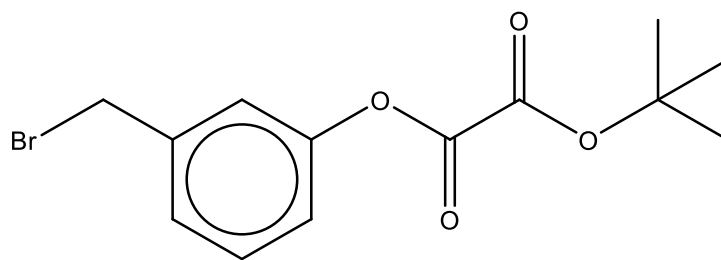
Ans: C

LiAlH_4 in dry ether – reduces RCOOH , Ketone only

H_2 – reduces alkene and Ketone only

Reducing Agent	Alkene	Carbonyl	Carboxylic Acid
H_2/Ni	Reduced to alkane	Reduced to alcohol	No rxn
LiAlH_4	No rxn	Reduced to alcohol	Reduced to alcohol
NaBH_4	No rxn	Reduced to alcohol	No rxn

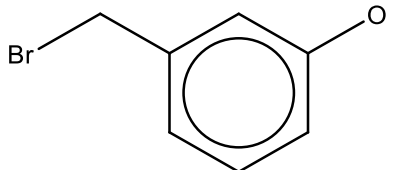
27 Compound Y reacts with hot alkaline aqueous manganate(VII).



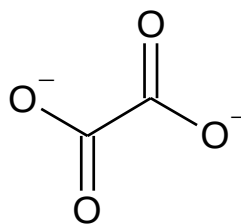
Compound Y

Which structure represents the organic product formed?

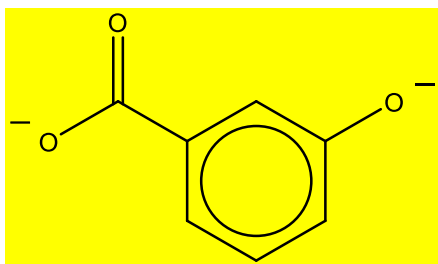
A



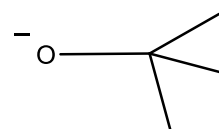
B



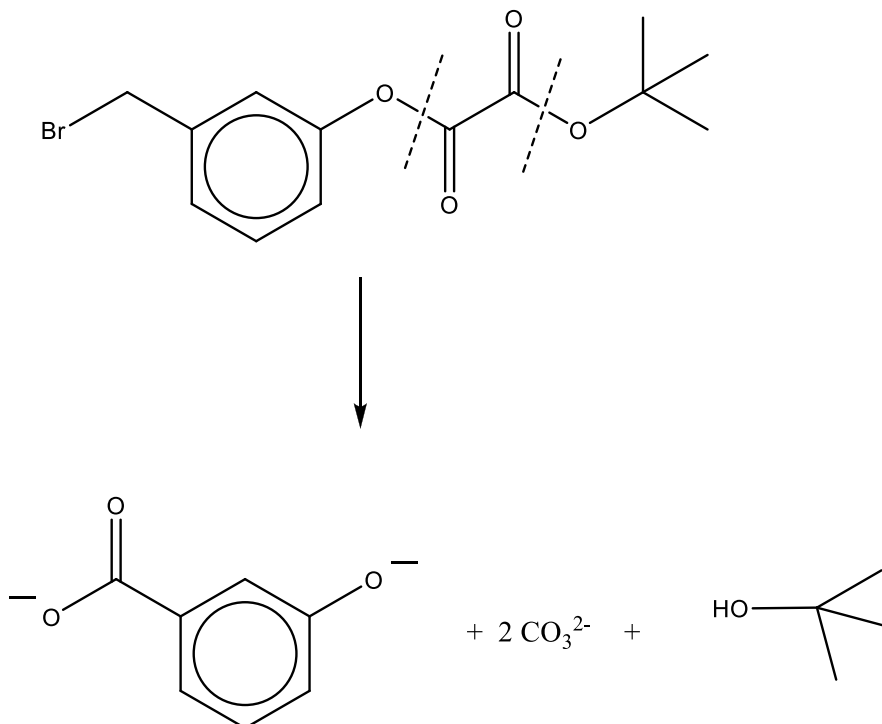
C



D



Ans: C



- 28 Benzylamine has the formula $\text{C}_6\text{H}_5\text{CH}_2\text{NH}_2$ and is a common precursor in organic synthesis.

Which statements about benzylamine is correct?

- A It can only be formed by the reduction of $\text{C}_6\text{H}_5\text{CN}$ by LiAlH_4 .
B It reacts with $\text{CH}_3\text{CO}_2\text{H}$ to form $\text{C}_6\text{H}_5\text{CH}_2\text{NHCOCH}_3$.
C It is formed by the reaction between $\text{C}_6\text{H}_5\text{NO}_2$ and tin in concentrated HCl .
D It reacts with excess $\text{CH}_3\text{CH}_2\text{Cl}$ under heat to form the compound, $\text{C}_{13}\text{H}_{22}\text{NCl}$.

Ans: D

Option A: R-CN can be reduced by H_2/Pt heat or LiAlH_4 in dry ether. Benzylamine can also be formed via nucleophilic substitution of $\text{C}_6\text{H}_5\text{CH}_2\text{Cl}$ with ammonia.

Option B: N in $\text{C}_6\text{H}_5\text{CH}_2\text{NH}_2$ uses its lone pair to accept H^+ from CH_3COOH (acid base reaction instead of nucleophilic acyl substitution (condensation)). Hence $(\text{CH}_3\text{COO}^-)(\text{C}_6\text{H}_5\text{CH}_2\text{NH}_3)^+$ is formed instead of $\text{C}_6\text{H}_5\text{CH}_2\text{NHCOCH}_3$. Amines do not form amides with carboxylic acids, unless the process is catalysed by a suitable enzyme! To form amides from amines, acyl chlorides are required.

Option C: $\text{C}_6\text{H}_5\text{NO}_2$ will be reduced to $\text{C}_6\text{H}_5\text{NH}_2$ which is isolated as $\text{C}_6\text{H}_5\text{NH}_3\text{Cl}$ due to acidic medium. But even if neutralised to give the amine, it is still not benzylamine as it is short of one carbon atom.

Option D: Correct answer. A quaternary ammonium salt is formed when $\text{C}_6\text{H}_5\text{CH}_2\text{NH}_2$ reacts with excess $\text{CH}_3\text{CH}_2\text{Cl}$.

- 29 Chiral bromoalkanes can undergo nucleophilic substitution with ethanolic KCN. The reaction mechanism is either $\text{S}_{\text{N}}1$ or $\text{S}_{\text{N}}2$.

Which statements are **incorrect**?

- 1 Inversion of configuration occurs in $\text{S}_{\text{N}}2$ mechanism.
- 2 KCN is involved in the rate determining step of $\text{S}_{\text{N}}1$.
- 3 Racemisation can occur in $\text{S}_{\text{N}}1$ mechanism.
- 4 The hydrolysis of primary bromoalkanes take place in $\text{S}_{\text{N}}1$ mechanism because there is very little steric hindrance between the nucleophile and the bromoalkanes.

A 1 and 2 only

B 2 and 4 only

C 2 and 3 only

D 1 and 3 only

Ans: B

Option 1: True. There is an inversion of configuration in the product since the Nu attacks from the back of the C-X bond.

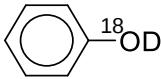
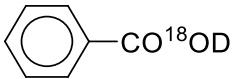
Option 2: False. Only halogenoalkanes is involved in the slow step of S_N1 .

Option 3: True. The Nu can attack the planar carbocation from either side with equal probability, hence a racemic mixture is formed.

Option 4: False. Primary halogenoalkane will favour S_N2 mechanism due to little steric hindrance.

- 30** Phenyl propanoate undergoes acid hydrolysis in the presence of a solution containing $D_2^{18}O$.

Which of the following products are formed?

- 1 $CH_3CH_2CO^{18}OD$
- 2 
- 3 

A 1 only

B 1 and 2 only

C 1 and 3 only

D 1, 2 and 3 only

Ans: A

