1 A sample of boron contains two naturally occurring isotopes, ^{10}B and ^{11}B. This sample has a relative atomic mass value of 10.75.

What is the percentage of the isotope ^{11}B in the sample?

A 20 **B** 25 **C** 75 **D** 80

Answer: **C**

Let % abundance of ^{11}B be m%.

$$10.75 = \frac{(m)(11)+(100-m)(10)}{100}$$

m = 75

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

On losing an electron, which particle would have the greatest number of unpaired electrons?

A C^-

B Fe^{3+}

C Ti^{2+}

D P

Answer: **B**

C^- forms C : [He] $2s^2 2p^2$ (2 unpaired electrons)
Fe^{3+} forms Fe^{4+} : [Ar] $3d^4$ (4 unpaired electrons)
Ti^{2+} forms Ti^{3+} : [Ar] $3d^1$ (1 unpaired electrons)
P forms P^+: [Ne] $3s^2 3p^2$ (2 unpaired electrons)

3 Particle **X** has a charge of +1 and a proton number, n.

Particle **Y** has a proton number of (n+1) and is isoelectronic with **X**.

Which of the following statements correctly describes **X** and **Y**?

A **X** and **Y** are isotopes.

B The atoms of **X** and **Y** have the same electronic configurations.

C **Y** has a charge of +1 and same charge density as that of **X**.

D **Y** has a charge of +2 and smaller ionic radius than **X**.

Answer: **D**

	X	**Y**
Proton number, n	n	n + 1
No of electrons	n – 1	n – 1
Charge	+1	+2

Option A is wrong
X and **Y** have different number of protons. Hence they cannot be isotopes.

Option B is wrong
X and **Y** have different number of protons. **X** atom has n electrons while **Y** has (n + 1) electrons. Hence **X** and **Y** atoms have different full electronic configurations.

Option C is wrong
Y has charge of +2 while it has same number of electrons as that of **X**. Hence, **Y** has smaller ionic radius. This leads to higher charge density.

Option D is correct
Y has charge of +2 while it has same number of electrons as that of **X**. Hence, **Y** has smaller ionic radius.

4 The Valence Shell Electron Pair Repulsion (VSEPR) Theory is used to predict the shapes of molecules or polyatomic ions.

Which of the following pairs of species are planar?

A F_2O and PF_5

B SO_3^{2-} and ClF_3

C BrF_4^- and NO_2

D ICl_5 and CO_2

Answer: **C**

F_2O	2 bp 1 lp	Bent	planar
PF_5	5 bp 0 lp	Trigonal bipyramidal	Non-planar
SO_3^{2-}	3 bp 1 lp	Trigonal pyramidal	Non-planar
ClF_3	3 bp 2 lp	T-shaped	Planar
BrF_4^-	**4 bp 2 lp**	**Square planar**	**Planar**
NO_2	**2 bp 1 lone e$^-$**	**Bent**	**Planar**
ICl_5	5 bp 1 lp	Square pyramidal	Non-planar
CO_2	2 bp 0 lp	linear	Planar

5 Which of these phenomena **cannot** be explained by hydrogen bonding?

1 NH_4Br has a higher boiling point than HBr.

2 Ice is less dense than water.

3 Dimerisation of NO_2 to form N_2O_4.

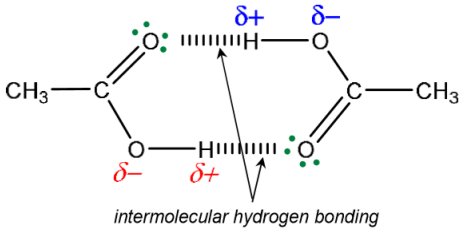
4 Ethanoic acid forms dimers which dissolved in organic solvents

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

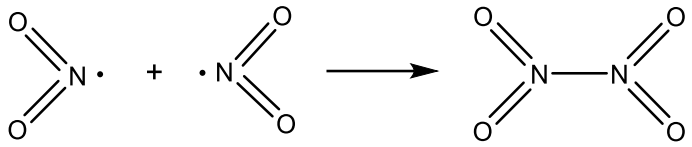
Answer: **B**

Larger amount of energy is needed to overcome the strong ionic bonds in NH_4Br than the weaker intermolecular permanent dipole-permanent dipole attraction in HBr.

When dissolved in organic solvents such as hexane, ethanoic acid form dimers by forming intermolecular hydrogen bonds between two ethanoic acid monomers.



Dimerisation of NO_2 radicals to N_2O_4.



Ice has a three-dimensional tetrahedral lattice with an open structure held by intermolecular hydrogen bonds. With the open structure, ice has less mass per unit volume (i.e. lower density) than water.

[Turn over

6 A 2.50 dm^3 vessel containing ethane gas at a pressure of 1.50 x 10^5 Pa is connected to a 7.50 dm^3 vessel containing methane gas at a pressure of 2.50 x 10^5 Pa. The gases are allowed to mix freely. The temperature of the system is then raised from 100 °C to 350 °C. *(Note that there is no chemical reaction between both gases)*

What is the final pressure of the system?

A 2.25 x 10^5 Pa

B 3.76 x 10^5 Pa

C 6.68 x 10^5 Pa

D 7.88 x 10^5 Pa

Answer: **B**

P_{ethane} = 1.50 x 10^5 x 2.50/10 = 3.75 x 10^4 Pa

$P_{methane}$ = 2.5 x 10^5 x 7.50/10 = 1.875 x 10^5 Pa

P_{total} = 3.75 x 10^4 + 1.875 x 10^5 = 2.25 x 10^5 Pa @ 100K

$$\frac{p_1}{T_1} = \frac{p_2}{T_2}$$

$$\frac{2.25 \times 10^5}{(100 + 273)} = \frac{p_2}{(350 + 273)}$$

p_2 = **3.76 x 10^5 Pa**

7 Which statements concerning only the elements in the third period, sodium to argon, are correct?

1 The element with the highest pH for its chloride in water is sodium.

2 The element with the highest electrical conductivity is aluminium.

3 The element with the highest melting point for its oxide is silicon

4 The element that has eight atoms in its molecule is sulfur.

A 1 and 4 only

B 2 and 3 only

C 1, 2 and 4 only

D 1, 3 and 4 only

Answer: **C**
All statements are correct except for option 3. MgO has highest melting point among Period 3 oxides.

8 The equations for three reactions are given below:

$$Cl_2(g) + H_2S(g) \rightarrow 2HCl(g) + S(s)$$

$$SO_2(g) + 2H_2S(g) \rightarrow 2H_2O(l) + 3S(s)$$

$$Cl_2(g) + 2H_2O(l) + SO_2(g) \rightarrow 2HCl(aq) + H_2SO_4(aq)$$

Which is the correct order of strength of the three reacting gases as oxidising agents?

	Strongest	⟶	**Weakest**
A	Cl_2	SO_2	H_2S
B	Cl_2	H_2S	SO_2
C	H_2S	SO_2	Cl_2
D	SO_2	H_2S	Cl_2

Answer: **A**

$$Cl_2(g) + H_2\overset{-2}{S}(g) \rightarrow 2HCl(g) + \overset{0}{S}(s)$$

$$SO_2(g) + 2H_2\overset{-2}{S}(g) \rightarrow 2H_2O(l) + 3\overset{0}{S}(s)$$

$$Cl_2(g) + 2H_2O(l) + \overset{+4}{S}O_2(g) \rightarrow 2HCl(aq) + H_2\overset{+6}{S}O_4(aq)$$

From equation (1) and (2), chlorine gas can oxidise both H2S and SO2, thus it is the strongest oxidizing agent.
From equation (1) and (2), hydrogen sulfide get oxidised by SO2 and HCl, thus it is the weakest oxidising agent.

[Turn over

9 The equation for the reaction of nitrogen monoxide with oxygen is shown below.

$$2NO(g) + O_2(g) \longrightarrow 2NO_2(g)$$

From initial rate experiments, the following rate equation was derived.

$$\text{Rate} = k[NO]^2[O_2]$$

The results of the initial rates experiments are shown.

initial [NO] / mol dm^{-3}	initial [O_2] / mol dm^{-3}	initial rate of formation of NO_2/ mol dm^{-3} s^{-1}
0.0010	0.002	7.00×10^{-6}
0.0020	0.003	**a**
b	0.004	1.26×10^{-4}

What are the missing values **a** and **b**?

	a	**b**
A	1.9×10^{-5}	0.0030
B	1.9×10^{-5}	0.0045
C	4.2×10^{-5}	0.0030
D	4.2×10^{-5}	0.0045

Answer: **C**

Rate = $k[NO]^2[O_2]$

Comparing 1st and 2nd experiment
[NO] doubled and [O_2] x1.5
so rate increases $2^2 = 4$ and increases another x1.5.
So total rate increases 4 x 1.5 = 6
⇨ Initial rate increases by $7 \times 10^{-6} \times 6 = 4.2 \times 10^{-5}$

Comparing 1st and 3rd experiment
Initial rate increased by $(1.26 \times 10^{-4}) / (7 \times 10^{-6}) = 18$
Since [O_2] doubled, means the rate must have increased by 18/2 = 9 times due to the increase in [NO].
⇨ [NO] must have increased by $\sqrt{9} = 3$ times
⇨ Value of [NO] is 0.003

10 Caffeine is a drug that increases the activity of the brain and nervous system. Its elimination from the body follows a first-order kinetics with a half-life of 5.0 h.

How long will it take for someone who took 50 mg of caffeine, to have 10 mg of caffeine left in his system?

A 5.0 h **B** 11.6 h **C** 25.0 h **D** 58.0 h

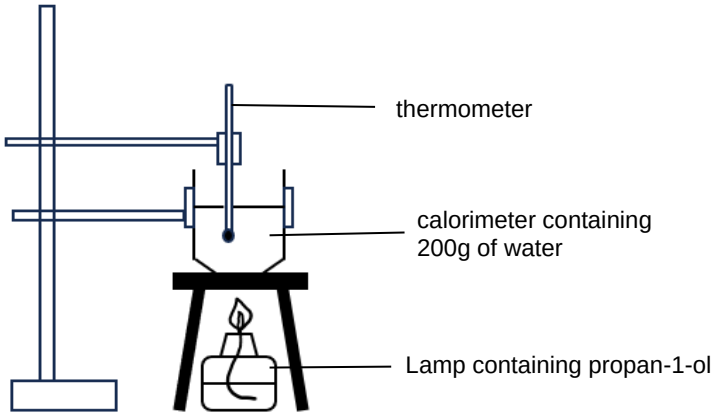
Answer: **B**

For first order kinetics,
t ½ = 5.0 h

$[A]_t = [A]_0 \times (½)^n$

$10 = 50 \times (½)^n$
⇨ n = 2.32
time = 2.32 x 5 = 11.6 h

11 A student carried out an experiment shown below to determine the enthalpy change of combustion of propan-1-ol (M_r = 60.0). It was found that the combustion of 1.0 g of propan-1-ol raises the temperature of 200 g of water by 40 °C.



Given that the enthalpy change of combustion of propan-1-ol is –2200 kJ mol^{-1}, what is the efficiency of the heat transfer process? Assuming the specific heat capacity of water is 4.18 J g^{-1} K^{-1}.

A 88.5 %

B 91.2 %

C 95.2 %

D 99.5 %

[Turn over

Answer: **B**

Heat absorbed by water = mcΔT = (200)(4.18)(40) = 33440J

Heat released by combustion of propan-1-ol = (2200 x 10^3)(1/60) = 36667J

Efficiency = 33440/36667 **= 91.2%**

12 For the reaction, $3C(s) + Cr_2O_3(s) \longrightarrow 2Cr(s) + 3CO(g)$ $\Delta H^{\ominus} = +1120$ kJ mol^{-1}

Which statement is correct?

A The reaction is spontaneous at all temperatures.

B The reaction is not spontaneous at any temperature.

C The reaction is spontaneous only at low temperature.

D The reaction is spontaneous only at high temperature.

Answer: **D**

ΔG = ΔH – TΔS
There is an increase in number of gaseous particles from 0 to 1 mol.
Since ΔH > 0 and ΔS > 0, ΔG < 0 (i.e. spontaneous) only at high temperatures.

13 Gaseous methanol undergoes the following reaction as shown below.

$$CH_3OH(g) \rightleftharpoons CO(g) + 2H_2(g) \qquad K_c = 5.0 \text{ mol}^2 \text{ dm}^{-6}$$

Determine the initial concentration of CH_3OH such that the equilibrium concentration of CH_3OH would be 2.0 mol dm^{-3}.

A 3.36

B 4.35

C 4.68

D 5.25

Answer: **A**

Let ***a*** be the initial concentration of CH_3OH.

	$CH_3OH(g)$ ⇌	$CO(g)$ +	$2H_2(g)$
Initial conc	a	0	0
Change in conc	– x	+ x	+ 2x
Equilibrium conc	2	x	2x

$$K_c = \frac{[H_2]^2[CO]}{[CH_3OH]} = 5$$

$$K_c = \frac{(2x)^2(x)}{(2)}$$

x = 1.357

a – x = 2

a = **3.36**

14 Ammonia is commonly used as fertiliser. In an experiment, 0.100 mol dm^{-3} of ammonia dissociates partially in the presence of water according to the equation below.

$$NH_3(aq) + H_2O(l) \rightleftharpoons NH_4^+(aq) + OH^-(aq)$$

Which of the following statements is correct?

A K_b of ammonia increases upon dilution.

B pH remains unchanged upon dilution.

C Ammonia acts as a Lewis base.

D The degree of dissociation of ammonia remains unchanged upon dilution.

Answer: **C**

Option A: K_b is temperature dependent only.

Option B: Upon dilution, $[OH^-]$ decreases. pH decreases.

Option C: NH_3 donates an electron pair to form dative bond with H^+ ion.

Option D: α increases since position of equilibrium shift right upon dilution.

15 The numerical value of the solubility product of magnesium phosphate, $Mg_3(PO_4)_2$, is 1.0×10^{-24}. What is the solubility of $Mg_3(PO_4)_2$?

A 1.00×10^{-12} mol dm^{-3}

B 6.21×10^{-6} mol dm^{-3}

C 1.11×10^{-5} mol dm^{-3}

D 1.86×10^{-5} mol dm^{-3}

[Turn over

Answer: **B**

$Mg_3(PO_4)_2 \rightleftharpoons 3Mg^{2+} + 2PO_4^{3-}$

3s 2s

$K_{sp} = [Mg^{2+}]^3 [PO_4^{3-}]^2$

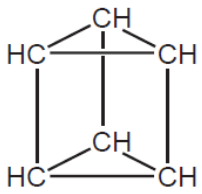
$1.0 \times 10^{-24} = (3s)^3 (2s)^2$

$1.0 \times 10^{-24} = 108s^5$

s = **$\underline{6.21 \times 10^{-6}}$**

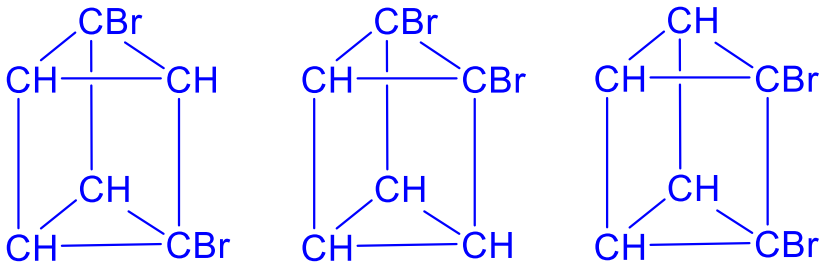
16 *Prismane* is an isomer of benzene which has a molecular formula of C_6H_6, in which one hydrogen atom is attached to each carbon atom. *Prismane* is far less stable than benzene.

How many di-brominated products, excluding stereoisomers, can *Prismane* form via free radical substitution?

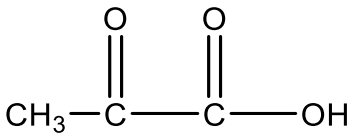


A 2 **B** 3 **C** 4 **D** 5

Answer: **B**
3 structural isomers are shown below.



17 What is the number of σ and π bonds in compound **K**?



Compound **J**

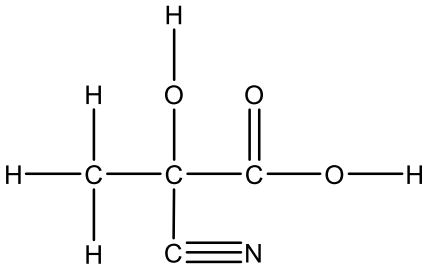
Compound **J** reacts with HCN under suitable conditions to form compound **K**.

What is the number of σ and π bonds in compound **K**?

	σ	π
A	9	2
B	12	3
C	13	3
D	14	4

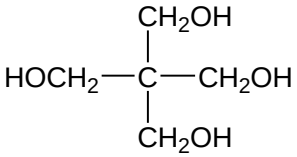
Answer**: B**

The displayed formula of compound K is shown below. It has 12σ and 3 π bonds.



[Turn over

18 Pentaerythritol is used as an intermediate in the manufacture of paint.



pentaerythritol

Which statement about pentaerythritol is correct?

A It can react with HBr (aq) via nucleophilic substitution.

B Its empirical and molecular formulae are different.

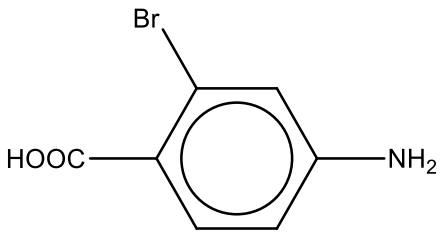
C It can undergo elimination with hot concentrated sulfuric acid to form an alkene.

D One mole of pentaerythritol gives two moles of hydrogen gas on reaction with excess sodium.

Answer**: D**

- A is incorrect as pentaerythritol only reacts with HBr gas.
- B is incorrect as both the empirical and molecular formulae is $C_5H_{12}O_4$.
- C is incorrect as the central C atom, which is the adjacent C atoms to all the C with –OH group does not contain any H for elimination to occur.
- D is correct. Since 1 mole of –OH reacts with sodium to form 0.5 mole of hydrogen gas, the presence of 4 –OH groups in pentaerythritol will produce 2 moles of hydrogen gas.

19 Compound **F** may be synthesised from methylbenzene.



Compound **F**

Which of the following synthetic routes will most likely yield compound **F**?

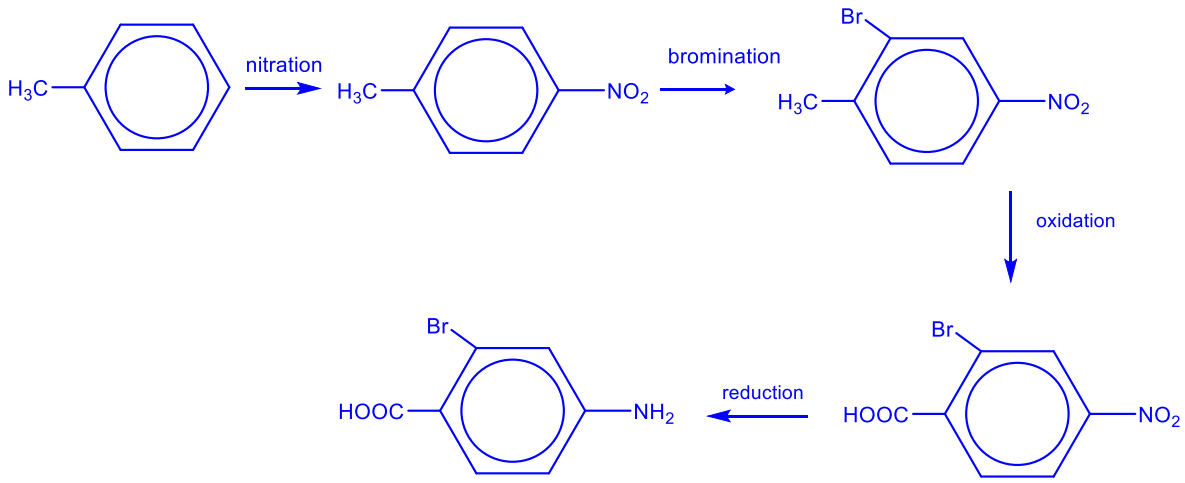
A nitration → bromination → oxidation → reduction

B bromination → oxidation → nitration → reduction

C bromination → nitration → oxidation → reduction

D nitration → reduction → bromination → oxidation

Answer: **A**



20 Which of the following could explain why benzene does not undergo electrophilic addition reaction?

1 Delocalised pi electrons stabilise the structure.

2 Benzene is unable to act as a nucleophile.

3 All carbon atoms in benzene are sp^2 hybridised.

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

Answer: **D**

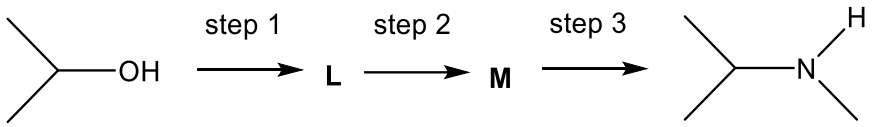
1 is correct. The six unbonded p electrons are completely delocalised (free to move throughout) in the π electron cloud above and below the plane of the ring. It is this delocalisation that gives benzene its extra stability, i.e. the benzene ring is *resonance stabilised.*

2 is incorrect. Benzene is electron-rich and can act as a nucleophile.

3 is incorrect. Cannot explain why benzene does not undergo electrophilic addition reaction even though it is a correct statement.

[Turn over

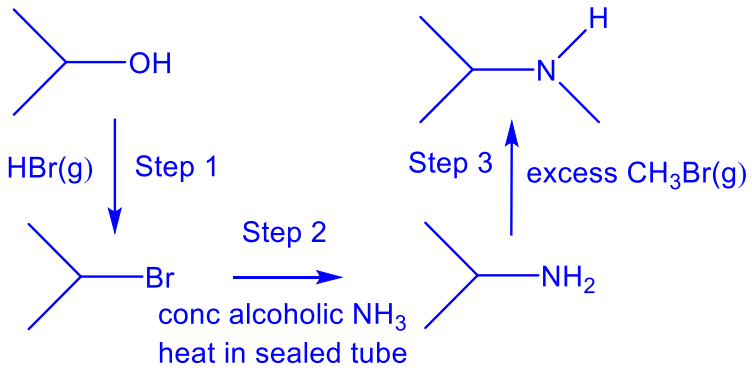
21 The following is a series of reactions involving propan–2–ol.



Which of the following give the correct reagents and conditions for steps 1, 2 and 3?

	step 1	step 2	step 3
A	alcoholic KCN, heat	H_2(g), Pt, high heat and pressure	excess CH_3Br(g)
B	HBr(g)	conc alcoholic NH_3, heat in sealed tube	excess CH_3Br(g)
C	HBr(g)	alcoholic KCN, heat	H_2(g), Pt, high heat and pressure
D	acidified $K_2Cr_2O_7$, heat	HCN, trace NaOH (aq), cold	H_2(g), Pt, high heat and pressure

Answer: **B**



22 Compounds **P** and **Q** have the following formulae:

$CHOCH(OH)COCH_3$	$CH_2(OH)CH_2OCOCH_3$
P	**Q**

Which of the following statements apply to these compounds?

1 Both react with 2,4–dinitrophenylhydrazine.

2 Both react with aqueous alkaline iodine

3 **P** reacts with Tollen's reagent but **Q** does not.

A 1, 2 and 3 are correct.

B 1 and 2 only are correct.

C 2 and 3 only are correct.

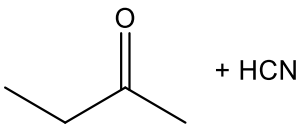
D 3 only is correct.

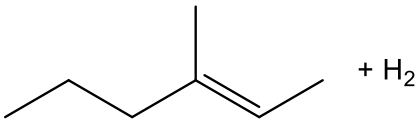
Answer: **D**

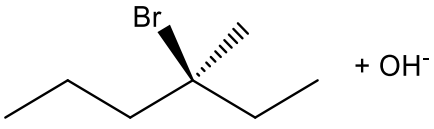
Compound P contains aldehyde, methyl ketone and a secondary alcohol.
- aldehyde and methyl ketone undergoes condensation with 2,4–DNPH.
- methyl ketone undergoes oxidation with aqueous alkaline iodine.
- aldehyde undergoes oxidation with Tollen's reagent.

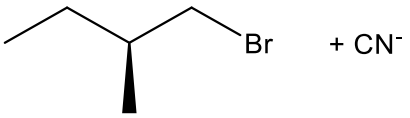
Compound Q contains primary alcohol and an ester.
There are no aldehyde or ketone, thus no reaction with Tollen's reagent or 2,4–DNPH.
There is no methyl alcohol thus no reaction with aqueous alkaline iodine.

23 Which reaction will **not** produce a mixture of two enantiomers?

A 

B 

C 

D 

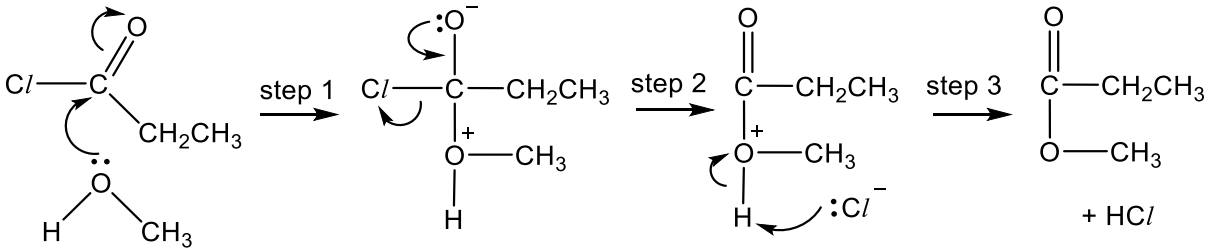
[Turn over

Answer: **D**

	Reaction	Reasoning	Racemic mixture formed
A	Nucleophilic addition	Trigonal planar sp^2 hybridised carbonyl C atom (intermediate)	√
B	Reduction	Product has 1 chiral carbon	√
C	Nucleophilic substitution (likely S_N1)	Trigonal planar sp^2 hybridised carbocation (intermediate)	√
D	Nucleophilic substitution (likely S_N2)	Pentavalent transition state	X

For reactions A,B and C, there is equal probability of nucleophile attacking trigonal planar carbon atom or carbocation from top or bottom of plane, thus producing equal amounts of enantiomers as products since the carbon atom in product is chiral.

24 The reaction sequence given shows a possible mechanism for the reaction between methanol and propanoyl chloride.



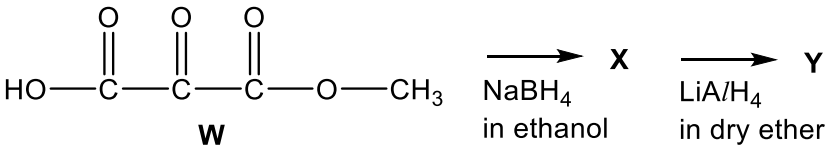
What are the types of reaction occurring in step 1 and 2?

	step 1	step 2
A	electrophilic addition	elimination
B	electrophilic addition	hydrolysis
C	nucleophilic addition	elimination
D	nucleophilic addition	hydrolysis

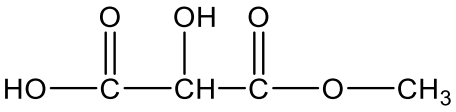
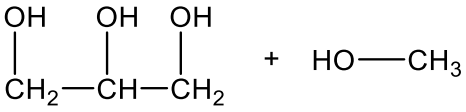
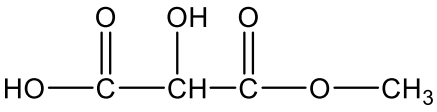
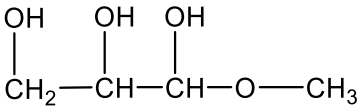
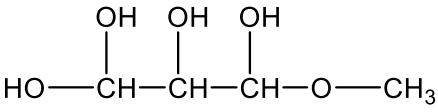
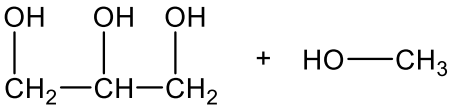
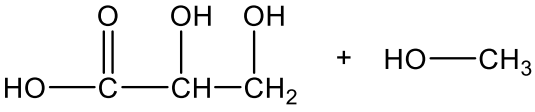
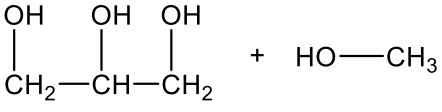
Answer: **C**

Overall reaction is a nucleophilic acyl substitution which involves a nucleophilic addition to a C=O bond followed by an elimination of a small molecule HCl.

25 The compound **W** shown below undergoes the two reactions as follows:



What could be compounds **X** and **Y**?

	X	**Y**
A		
B		
C		
D		

Answer: **A**

Functional groups present: carboxylic acid, ketone, ester.
$NaBH_4$ reduces only the ketone to form secondary alcohol.
$LiAlH_4$ subsequently reduces the carboxylic acid into primary alcohol and ester into corresponding alcohols.

26 Nitrobenzene reacts with tin in concentrated hydrochloric acid followed by aqueous sodium hydroxide to form phenylamine.

Which of the following statements is correct for the above reaction?

A Tin is used as a catalyst in this reaction.

B The oxidation number of the oxygen atom decreased in this reaction.

C $LiAlH_4$ is a suitable alternative to carry out this conversion.

D NaOH is required to form phenylamine from phenylammonium chloride.

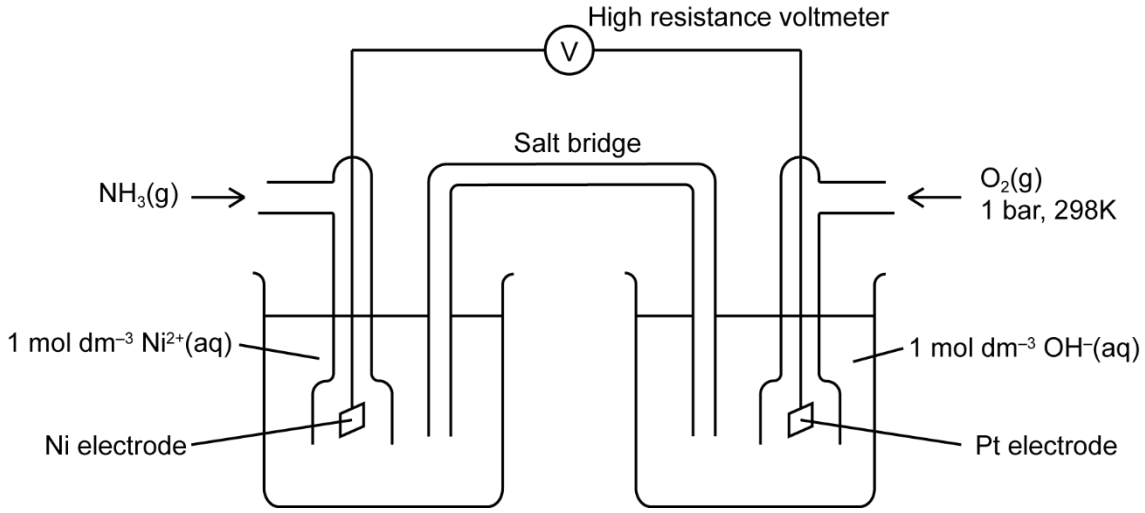
[Turn over

Answer: **D**

Option A incorrect. Sn is oxidised to Sn^{2+} in this reaction; it is not the catalyst but the reducing agent.
Option B incorrect. The oxidation number of **nitrogen** decreased from +2 in nitrobenzene to –3 in phenylamine.
Option C incorrect. $LiAlH_4$ cannot be used as it will give rise to other products.
Option D correct. The salt of phenylammonium chloride is formed due to the acid-base reaction between phenylamine formed after reduction of nitrobenzene, with the hydrochloric acid used in the reduction process. The free phenylamine is liberated on the addition of NaOH.

27 *Use of Data Booklet is relevant to this question.*

An electrochemical experiment was set up, and then ammonia gas passing through the left electrolyte until it reached saturation.



Using the given information and relevant data from the Data Booklet, determine the resultant cell potential.

A +0.65 V **B** +0.91 V **C** +1.48 V **D** +1.74 V

Answer: **B**

Relevant equations:

$O_2 + 2H_2O + 4e^- \rightleftharpoons 4OH^-$ $E = +0.40$ V

$[Ni(NH_3)_6]^{2+} + 2e^- \rightleftharpoons Ni + 6NH_3$ $E = -0.51$ V

$E^0_{cell} = (+0.40) - (-0.51) = +0.91$ V

28 An aqueous solution of copper(II) nitrate is electrolysed for 25 min with a constant current of 3.0 A. What is the expected gain in mass of the cathode?

A 0.025 g **B** 0.68 g **C** 1.5 g **D** 3.0 g

Answer: **C**

Mass = (25 × 60) × 3.0 ÷ (96500 x 2) × 63.5 = 1.5 g

29 Which statement correctly describes the difference between magnesium metal and titanium metal?

1 For two identical samples, the mass of magnesium is less than the mass of titanium.

2 Magnesium melts at a lower temperature than titanium.

3 Titanium has catalytic properties while magnesium does not.

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

Answer: **A**

This question is meant to contrast between s-block metals (exemplified by magnesium) and transition metals (exemplified by titanium)

1: Transition metals are denser than s-block metals

2: Transition metals have higher melting points than s-block metals

3: Transition metals has catalytic properties

30 Which of the following processes does **not** involve a change in colour of the solution?

A Adding Zn(s) to $V(NO_3)_2$(aq)

B Adding $Na_2S_2O_3$(aq) to I_2(aq)

C Adding concentrated HC*l* to $Cu(NO_3)_2$(aq)

D Adding methanoic acid to acidified $KMnO_4$.

Answer: **A**

A: no redox
B: redox
C: ligand exchange
D: oxidation

[Turn over

1	2	3	4	5	6	7	8	9	10
C	**B**	**D**	**C**	**B**	**B**	**C**	**A**	**C**	**B**
11	12	13	14	15	16	17	18	19	20
B	**D**	**A**	**C**	**B**	**B**	**B**	**D**	**A**	**D**
21	22	23	24	25	26	27	28	29	30
B	**D**	**D**	**C**	**A**	**D**	**B**	**C**	**A**	**A**