Catholic Junior College
JC 2 Preliminary Examinations
Higher 2

CANDIDATE NAME	
CLASS	**2T**

CHEMISTRY 9729/01

Paper 1 Multiple Choice **15 September 2022**

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, class and NRIC/FIN number 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.

Read the instructions on the Answer Sheet very carefully.

Each correct answer will score one mark. A mark will not be deducted for a wrong answer.
Any rough working should be done in this booklet.
The use of an approved scientific calculator is expected, where appropriate.

WORKED SOLUTIONS

This document consists of **31** printed pages.

1 Which statement about 27 g of A*l* is always correct?

A It contains the same number of atoms as $\frac{1}{12}$ g of ^{12}C.

B It contains the same number of atoms as 24 dm^3 of krypton gas at room temperature and pressure.

C It contains the same number of hydrogen ions as 1 dm^3 of 1 mol dm^{-3} aqueous sulfuric acid.

D It contains the same number of atoms as 28 g of nitrogen gas.

Topic: Mole Concept

No of A*l* atoms in 27 g = $\frac{27}{27.0}$ x 6.02 x 10^{23} = 6.02 x 10^{23}

A **No of C atoms in $\frac{1}{12.0}$ g of ^{12}C = $\frac{\frac{1}{12}}{12.0}$ x 6.02 x 10^{23} = 4.18 x 10^{21}**

B **No of Kr atoms in 24 dm^3 of Kr = $\frac{24}{24.0}$ x 6.02 x 10^{23} = 6.02 x 10^{23}**

C **$H_2SO_4 \equiv 2H^+$**

No of H^+ ions in 1 dm^3 of aq H_2SO_4 = 1 x 1 x 2 x 6.02 x 10^{23}

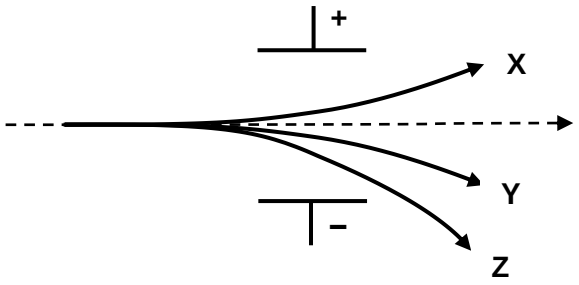
= 1.20 x 10^{24}

D **$N_2 \equiv 2N$**

No of N atoms in 28 g of N_2 = $\frac{28}{28.0}$ x 2 x 6.02 x 10^{23} = 1.20 x 10^{24}

Answer: B

2 The following are flight paths of charged particles as they pass through an electric field at the same speed.



Which of the following correctly identifies **X**, **Y** and **Z**?

	X	Y	Z
A	$^{14}N^-$	$^{16}O^{2+}$	$^{28}Si^{2+}$
B	$^{14}N^-$	$^{14}C^+$	$^{28}Si^{4+}$
C	$^{15}O^+$	$^{14}C^+$	$^{14}N^+$
D	$^{15}O^-$	$^{14}C^+$	$^{28}Si^+$

Concept: Angle of deflection

particles	$^{14}N^-$	$^{14}C^+$	$^{28}Si^{4+}$
m/z	1/14	1/14	4/28 = 1/7

$$\text{angle of deflection} \propto \frac{\text{charge}}{\text{mass}} \text{of particle}$$

$^{14}N^-$ is negatively charged, so it is attracted to anode while $^{14}C^+$ and $^{28}Si^{4+}$ are attracted to cathode. Since angle of deflection is charge/mass ratio, $^{14}N^-$ and $^{14}C^+$ have roughly the same angle of deflection (paths X and Y), while $^{28}Si^{4+}$ has almost double the angle of deflection (path Z).

Answer: B

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

Species containing one or more unpaired electrons can be attracted by an external magnetic field and are said to be paramagnetic.

Which of the following species is paramagnetic?

1 Cr^{3+}
2 Cu^+
3 Ni^{2+}

A 3 **B** 1 and 2

C 1 and 3 **D** 1, 2 and 3

Concept: Electronic Configuration

Cr^{3+}: $[Ar]3d^3$

Cu^+: $[Ar]3d^{10}$ (Does not have any unpaired electrons)

Ni^{2+}: $[Ar]3d^8$

Answer: C

4 In which of the following sequences are the species quoted in order of decreasing boiling points?

A RbC*l*, KC*l*
B HF, HC*l*
C K, Ca
D CO, CO_2

Concept: Boiling points

Option A: Both of them have giant ionic lattice structure with strong electrostatic forces of attractions between cations and anions. The strength of ionic bonding α $\left|\frac{q_+ \cdot q_-}{r_+ + r_-}\right|$

Rb^+ has larger cationic size than K^+, hence RbC*l* has weaker ionic bonding than KC*l*.

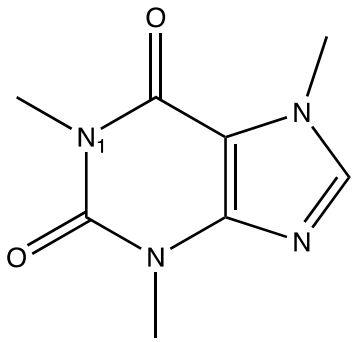
Option B: HF has a higher boiling point than HC*l* as it has stronger intermolecular hydrogen bonding while HC*l* has weaker permanent dipole-permanent dipole between its molecules.

Option C: Both K and Ca have giant metallic lattice structure with strong electrostatic forces of attractions between cations and sea of delocalised electrons. The strength of metallic bonding α the number of valence electrons involved in the delocalisation.
K: $4s^1$
Ca: $4s^2$
Ca has higher boiling point than K because it has more valence electrons than K involved in the delocalisation.

Option D: Both of them have simple molecular structure. CO_2 has larger electron cloud size compared to CO. CO_2 has higher boiling point as it has stronger intermolecular instantaneous dipole-induced dipole attractions between its molecules compared to the weaker intermolecular permanent dipole-permanent dipole between CO molecules.

Answer: B

5 People drink beverages containing caffeine to relieve or prevent drowsiness and to improve cognitive performance.



Caffeine

Which statement about caffeine is true?

A Caffeine molecule has a planar structure.
B The π bond in C=C is formed by sideways overlap of 2p orbitals.
C The nitrogen atom in caffeine, N_1 is basic.
D There are 16 sigma bonds in a caffeine molecule.

Concept: Chemical Bonding

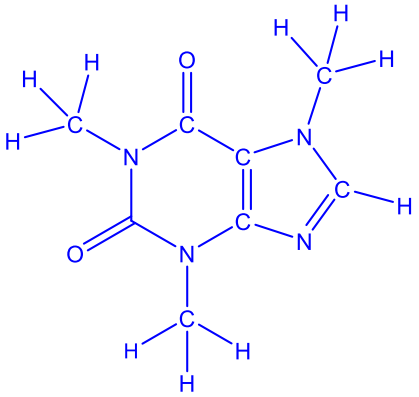
Option A is wrong. There are sp^3 carbon atoms which have tetrahedral geometry.

Option B is correct. The pi bond is formed by sideways overlap of parallel unhybridised p orbitals.

Option C is wrong. The lone pair of electrons in the unhybridised p orbital of N_1 has overlapped sideways with the adjacent π electron cloud of C=O bond resulting in the delocalisation of lone pair of electrons. Hence, lone pair of electrons is unavailable for protonation.

Option D is wrong. There are 25 σ bonds in a caffeine molecule. There is one σ bond and one π bond in a double bond.

Answer: D



6 Which of the following substances conduct electricity due to delocalised electrons?

1 Graphite
2 Solid magnesium
3 Molten sodium chloride

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

Concept: Physical properties of compounds

Answer: B

Molten sodium chloride conducts electricity due to the presence of free mobile ions.

7 Which of the following statements is **incorrect**?

A When methane gas is subjected to low pressure, it liquefies.
B Tyre pressure readings are higher on a hot day.
C The boiling point of water is lower than 100ºC at a higher altitude.
D The density of an ideal gas at constant pressure is inversely proportional to the temperature.

Concept: Gaseous State

A: Gas should be subjected to high pressure for it to be liquified.

B: P ∝ T, when tyre is hot, T increases hence pressure is higher.

C: At a higher altitude than sea level, the atmospheric pressure is lower than atmospheric pressure at sea level, thus boiling point will be lowered as P ∝ T.

D: $\rho = \frac{PM}{RT}$ density is inversely proportional to temperature.

Answer: A

8 For the oxides of Period 3 elements (Na to P), which property decreases from Na_2O to P_4O_{10}?

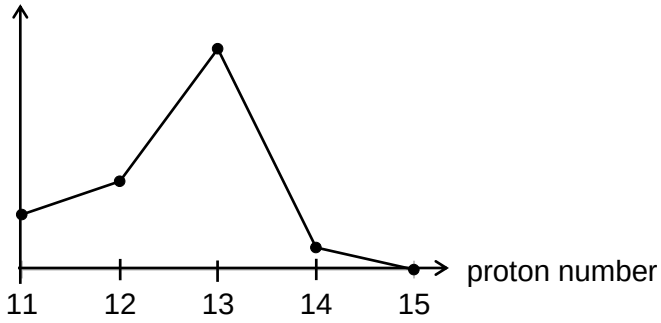
A melting point **B** covalent character

C pH when mixed with water **D** solubility in aqueous alkali

Concept: Properties of oxides of Period 3
Answer: C

Oxide formula		Na_2O	MgO	Al_2O_3	SiO_2	P_4O_6 and P_4O_{10}
Structure		Giant ionic			Giant covalent	Simple covalent (molecular)
Melting Point / ^oC		1280	2900	2040	1610	24 580
Acid/base behaviour		Basic: **Na**$_2$O + $2H^+ \rightarrow 2Na^+ + H_2O$	Basic: **Mg**O + $2H^+ \rightarrow Mg^{2+} + H_2O$	Amphoteric: **Al**$_2O_3$ + $6H^+ \rightarrow 2Al^{3+} + 3H_2O$ **Al**$_2O_3$ + $2OH^- + 3H_2O \rightarrow 2Al(OH)_4^-$	Acidic: forms SiO_3^{2-} with base **Si**O_2 + $2NaOH \rightarrow Na_2SiO_3 + H_2O$ **Si**O_2 + $CaO \rightarrow CaSiO_3$	Acidic **P**$_4O_6$ + $8NaOH \rightarrow 4Na_2HPO_3 + 2H_2O$ P_4O_{10} + $12NaOH \rightarrow 4Na_3PO_4 + 6H_2O$
Rxn w/H_2O	**Eqn**	$Na_2O + H_2O \rightarrow 2NaOH$	$MgO + H_2O \rightleftharpoons Mg(OH)_2$ (slightly alkaline as only mildly soluble)	**Giant ionic** with high lattice energy. Will not dissolve in water.	**Giant covalent.** Will not dissolve.	$P_4O_6 + 6H_2O \rightarrow 4$**H$_3PO_3$** $P_4O_{10} + 6H_2O \rightarrow 4$**H$_3PO_4$**
	pH	13	9	**7 (the pH of water)**	**7 (the pH of water)**	2

9 The following graph shows how a property of the elements in Period 3, from Na to P, or their compounds, varies with proton number.



What property is shown by the graph?

A ionisation energies of elements
B melting point of element
C pH of aqueous chloride
D electrical conductivity of element

Concept: Trends of different physical properties of Period 3 elements.

Electrical conductivity increases from Na to Al due to the increase in number of mobile delocalised electrons. Electrical conductivity then decrease to Si as Si is a semi-conductor and has poor conductivity under normal conditions. P does not conduct electricity as it neither have delocalised electrons nor mobile charge carriers.

Answer: D

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

The $\Delta G^{\ominus}_{solution}$ and $\Delta S^{\ominus}_{solution}$ for silver chloride, AgC*l* are +55.6 kJ mol^{-1} and +33.2 J mol^{-1} K^{-1} respectively.

What is the standard enthalpy change ($\Delta H^{\ominus}$) when 287 g of AgC*l* is precipitated under the same conditions?

A +65.5 kJ **B** −65.5 kJ **C** +131 kJ **D** −131 kJ

Concept: Gibbs' Free Energy

Amount of AgC*l* precipitated = $\frac{287}{107.9+35.5} = 2.00\ mol$

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

$55.6 = \Delta H^{\ominus}_{solution} - (298)(0.0332)$

AgC*l* (s) ⇌ Ag^+ (aq) + Cl^- (aq) $\Delta H^{\ominus}_{solution}$ = +65.49 kJ mol^{-1}

Ag^+ (aq) + Cl^- (aq) ⇌ AgC*l* (s) $\Delta H^{\ominus}_{ppt}$ = –65.49 kJ mol^{-1}

For 2 mol of AgC*l* precipitated, standard enthalpy change is –131 kJ.

Answer: D

11 The rate equation for a reaction between **A** and **B** is given by: rate = *k*[**A**]
Which of the following statements about the reaction is true?

1 **A** is involved in the rate−determining step in the reaction mechanism.
2 The rate constant, *k*, increases with increasing concentration of **A**.
3 A graph of rate against [**A**] gives a straight line that passes through the origin.

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

Concept: Reaction mechanism

1. True statement. From the rate equation, 1 molecule of A is involved in the rate determining step of the reaction.
2. False. Rate constant, *k*, is only affected by temperature and catalyst.
3. True statement. From the rate equation, rate is directly proportional to [A] hence is reflected as a straight line passing through the origin.

Answer: B

12 What is the pH of the final solution when V cm^3 of dilute nitric acid of pH 2.0 is mixed with V cm^3 of dilute nitric acid of pH 4.0 followed by the addition of 2V cm^3 of water?

A 2.3 **B** 2.6 **C** 3.0 **D** 3.6

Topic: Chemistry of aqueous solutions
Concept: Calculation of pH of acidic solutions

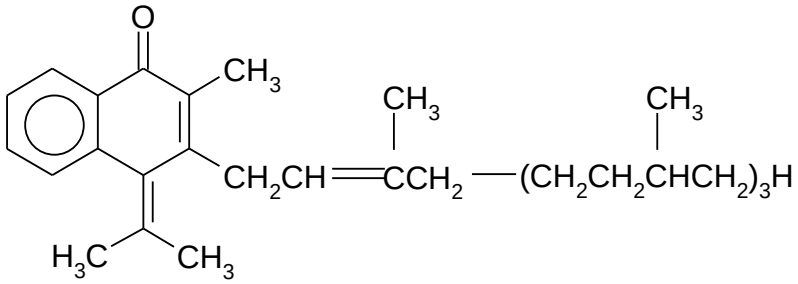
Total volume of final solution = V + V + 2V = 4V cm^3
Total amount of H^+ ions in final solution = $(10^{-2} \times \frac{V}{1000}) + (10^{-4} \times \frac{V}{1000})$ mol

$[H^+]$ in final solution = $\frac{(10^{-2} \times \frac{V}{1000}) + (10^{-4} \times \frac{V}{1000})}{\frac{4V}{1000}}$ = 0.002525 mol dm^{-3}

pH of final solution = - log (0.002525) = 2.6

Answer: B

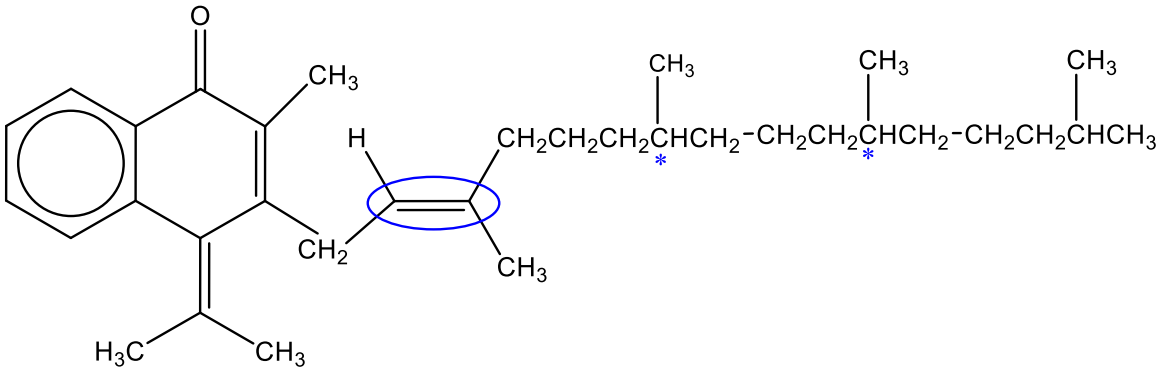
13 Compound **K** is a yellow viscous oil found in plants. It has the following structure.



What is the total number of stereoisomers for compound **K**?

A 4 **B** 8 **C** 16 **D** 32

Topic: Stereoisomerism



There are 2 chiral carbons and 1 carbon-carbon double bond that can display cis-trans isomerism. Therefore n =3
No. of stereoisomers = 2^3
= 8

Answer: B

14 In the free radical substitution reaction of methane, CH_4, one of the side-products formed is ethane, CH_3CH_3, which is formed when two $\bullet CH_3$ radicals combine.
Upon careful heating, a sample of butane, $CH_3CH_2CH_2CH_3$, reacted with chlorine gas in a free radical substitution reaction to give only mono-substituted products.

How many possible organic side-products would be obtained in this reaction when the radicals produced combine with each other?

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

Topic: Free Radical substitution

Only 2 organic radicals are produced in the mono-substitution of $CH_3CH_2CH_2CH_3$:

$CH_3CH_2\overset{\bullet}{C}HCH_3$ and $CH_3CH_2CH_2CH_2\overset{\bullet}{}$

Therefore, there can be 3 different products:
$CH_3CH_2CH_2CH_2CH_2CH_2CH_2CH_3$, $CH_3CH_2CH(CH_3)CH_2CH_2CH_2CH_3$, and $CH_3CH_2CH(CH_3)CH(CH_3)CH_2CH_3$.

Answer: B

15 The reaction between carbon dioxide and potassium hydroxide is exothermic. The proposed two–step mechanism of the reaction is shown below:

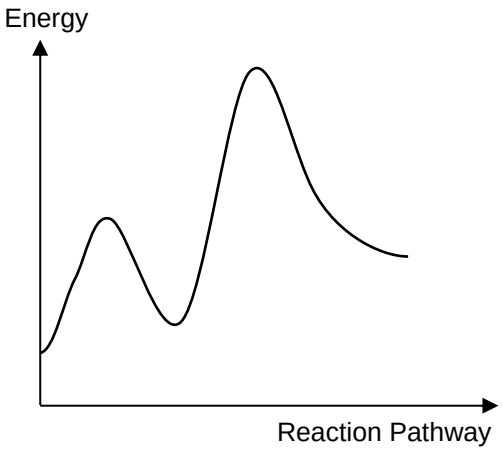
Step 1: $CO_2(aq) + KOH(aq) \rightarrow KHCO_3(aq)$
Step 2: $KHCO_3(aq) + KOH(aq) \rightarrow K_2CO_3(aq) + H_2O(l)$

Experiments were carried out to study the rate of the reaction above.

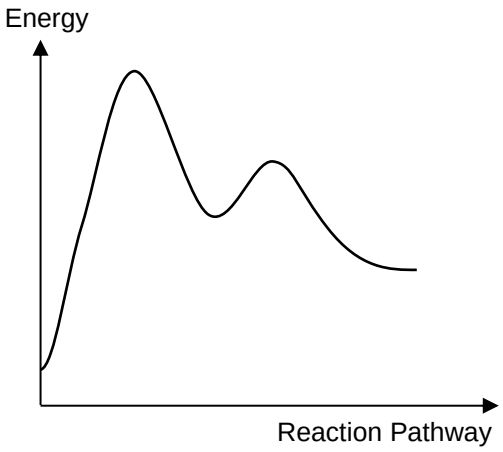
Experiment Number	Initial concentration of CO_2 / mol dm^{-3}	Initial concentration of KOH / mol dm^{-3}	Initial reaction rate / mol dm^{-3} s^{-1}
1	0.2	0.2	0.0034
2	0.4	0.2	0.0068
3	0.2	0.1	0.0017

Which of the following graphs most likely describes the energy profile of the reaction above?

A

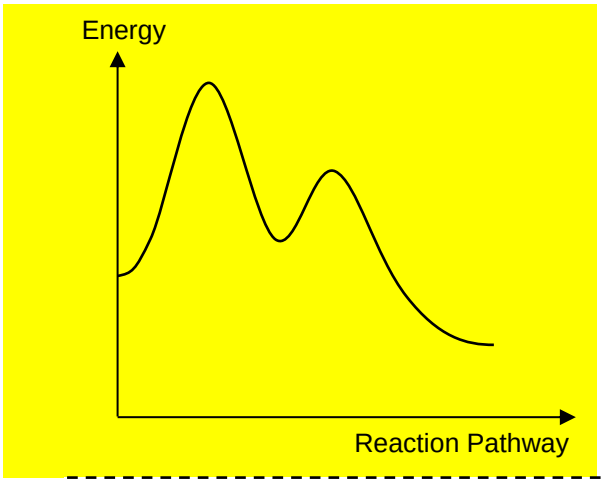


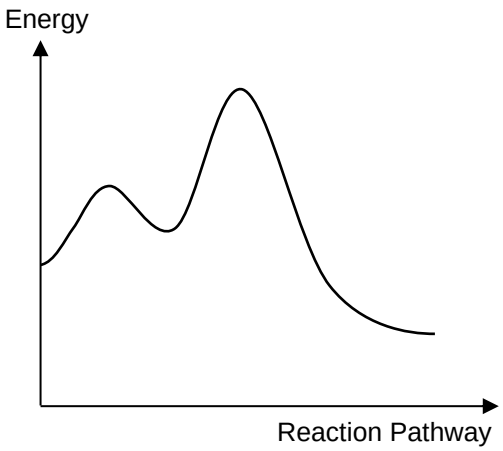
B



C

D





Concept: Kinetics (Reaction mechanism and order of reactions)
Answer: C

Comparing Expts 1 and 2, using the inspection method, by keeping concentrations of KOH constant, while doubling the concentration of CO_2, the rate doubles. Hence, the rate of reaction is directly proportional to $[CO_2]$.
Therefore the reaction is first order wrt CO_2.

Comparing Expts 1 and 3, using the inspection method, by keeping concentrations of CO_2 constant, while halving the concentration of KOH, the rate is halved. Hence, the rate of reaction is directly proportional to [KOH].
Therefore the reaction is first order wrt KOH.

Rate = $k[CO_2][KOH]$

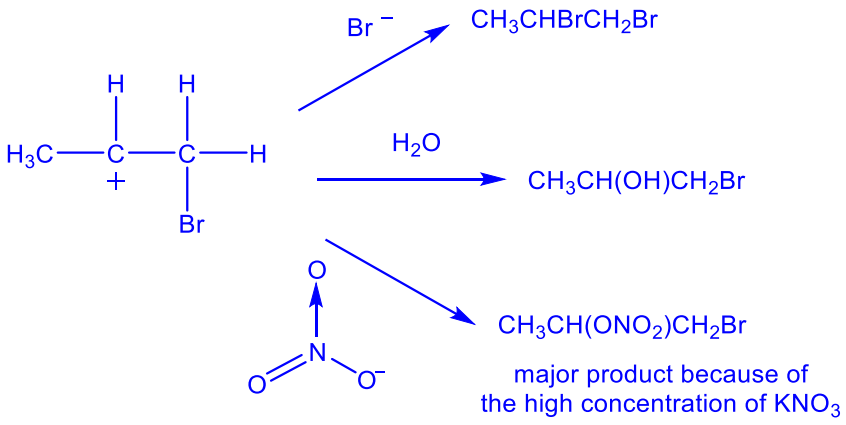
Based on the rate equation, it can be inferred that 1 molecule of CO_2 reacts with 1 molecule of KOH in the rate determining step, i.e. slow step which corresponds to step 1 of the reaction mechanism proposed.
Since the slow step has a high activation energy and is an overall exothermic reaction, therefore the graph reflected corresponds to option C.

16 Aqueous bromine can react with propene in the presence of concentrated potassium nitrate solution.

Which of the following is the major product formed in the reaction?

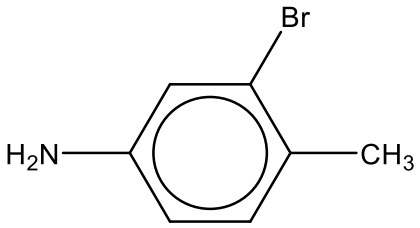
A $CH_3CHBrCH_2ONO_2$
B $CH_3CHBrCH_2Br$
C $CH_3CHBrCH_2OH$
D $CH_3CH(ONO_2)CH_2Br$

Topic: Alkenes
Concept: Electrophilic addition, Markovnikov's rule



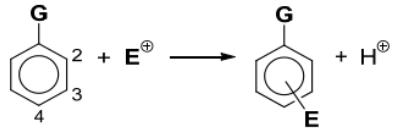
In the second step of the reaction, the nitrate ion is preferred relative to water owing to its negative charge.
Answer: D

17 Which synthetic route is most likely to lead to the most successful synthesis of the following product from benzene?



A nitration, bromination, alkylation, reduction
B nitration, bromination, reduction, alkylation
C nitration, alkylation, reduction, bromination
D alkylation, bromination, nitration, reduction

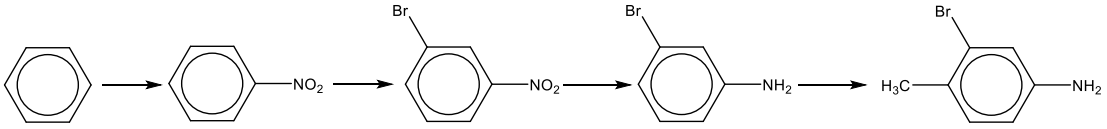
Topic: Arenes
Concept: Orientating effect of groups in aromatic substitution reactions



G	–alkyl –OH or –OR –NH_2, –NHR or –NR_2 –NHCOR	–Cl, –Br, –I	–CHO, –COR –CO_2H, –CO_2R –NH_3^+ –NO_2, –CN
Reactivity of ring (compared to benzene)	Activated	Deactivated	Deactivated
Position of E (relative to position of G)	2- and/or 4-	2- and/or 4-	3-

Option A results in a contest between the –NO_2 and –Br groups to determine the position of the –CH_3 group

Option B will result in the best yield because the –NH_2 and –Br groups are both –2,4–directing and will reinforce each other's activating effects on the incoming –CH_3.



Option C results in a contest between the –NO_2 and –CH_3 groups to determine the position of the Br group.

Option D results in a contest between the –Br and –CH_3 groups to determine the position of the NO_2 group.

Answer: B

18 A few drops of 1–chlorobutane, 1–bromobutane, 1–iodobutane were placed separately into three test–tubes each, containing 1.0 cm^3 of aqueous silver nitrate at 60 °C.

A hydrolysis reaction occurred. (X is the halogen atom)

$H_2O + CH_3CH_2CH_2CH_2X + Ag^+ \rightarrow CH_3CH_2CH_2CH_2OH + AgX + H^+$

Which of the following would be the best explanation for the rate of the reaction?

A The bond energy of C–X bond decreases from C–Cl to C–I.
B The bond polarity of C–X bond decreases from C–Cl to C–I.
C The electron deficiency of the carbon atom bonded to X decreases from C–Cl to C–I.
D The solubility of AgX decreases from AgCl to AgI.

Topic: Halogen Derivatives
Concept: Hydrolysis in RX

Answer: A
Bond energy of C–X (kJ mol^{-1}) : C–C*l* (340) > C–Br (280) > C–I (240).
The rate of hydrolysis increases from $CH_3CH_2CH_2CH_2Cl$ to $CH_3CH_2CH_2CH_2I$. The rate of hydrolysis is determined by the bond energy of C–X bond.
The bond energy of C–X bond decreases from C–C*l* to C–I.
Ease to break the C–X bond increases from C–C*l* to C–I.

19 Concentrated ammonia was heated in a sealed tube with excess bromoethane. Which of the following product will **not** be formed?

A $C_4H_{10}N$
B $C_4H_{11}N$
C $C_6H_{15}N$
D $C_8H_{20}NBr$

Topic: Halogen derivatives
Concept: Alkylation of nitrogen compounds

$C_2H_5Br + NH_3 \rightarrow C_2H_5NH_2$
$C_2H_5Br + C_2H_5NH_2 \rightarrow (C_2H_5)_2NH$
$C_2H_5Br + (C_2H_5)_2NH \rightarrow (C_2H_5)_3N$
$C_2H_5Br + (C_2H_5)_3N \rightarrow (C_2H_5)_4N^+Br^-$

Answer: A

20 An alcohol **A** with molecular formula $C_4H_{10}O$ is oxidised by acidified potassium dichromate(VI) under certain conditions to give **B**. The following shows some properties of **B**:

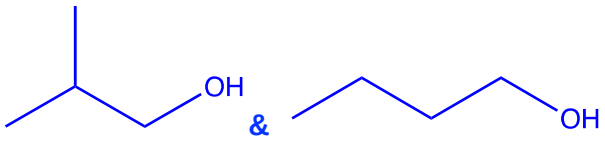
1 **B** does not produce a yellow precipitate with aqueous alkaline iodine.
2 **B** gives a brick – red precipitate when reacted with Fehling's solution.

How many isomers of alcohol **A** could result in the observations for **B**?

A 1 **B** 2 **C** 3 **D** 4

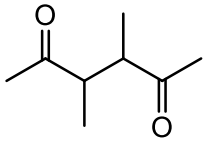
Concept: Reactions of alcohols
Answer: B

Since product B does not produce a yellow precipitate, it can be concluded that B does not contain a secondary alcohol with a methyl group.
Since product B gives a brick-red precipitate when reacted with Fehling's solution, an aliphatic aldehyde functional group is present.
Since aldehydes are formed from controlled oxidation of primary alcohol, the possible structures of primary alcohol from $C_4H_{10}O$ are:



Therefore, there are 2 isomers.

21 Compound **Z** shown below is an intermediate used to generate pyrroles which are essential to the production of many different chemicals in the pharmaceutical industry.



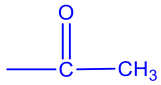
compound **Z**

Which sentence is correct for compound **Z**?

A It produces a silver mirror with Tollens' reagent.
B It decolourises acidified potassium manganate(VII).
C It produces a yellow precipitate with aqueous alkaline iodine.
D It does not produce an orange precipitate with 2,4-dinitrophenylhydrazine.

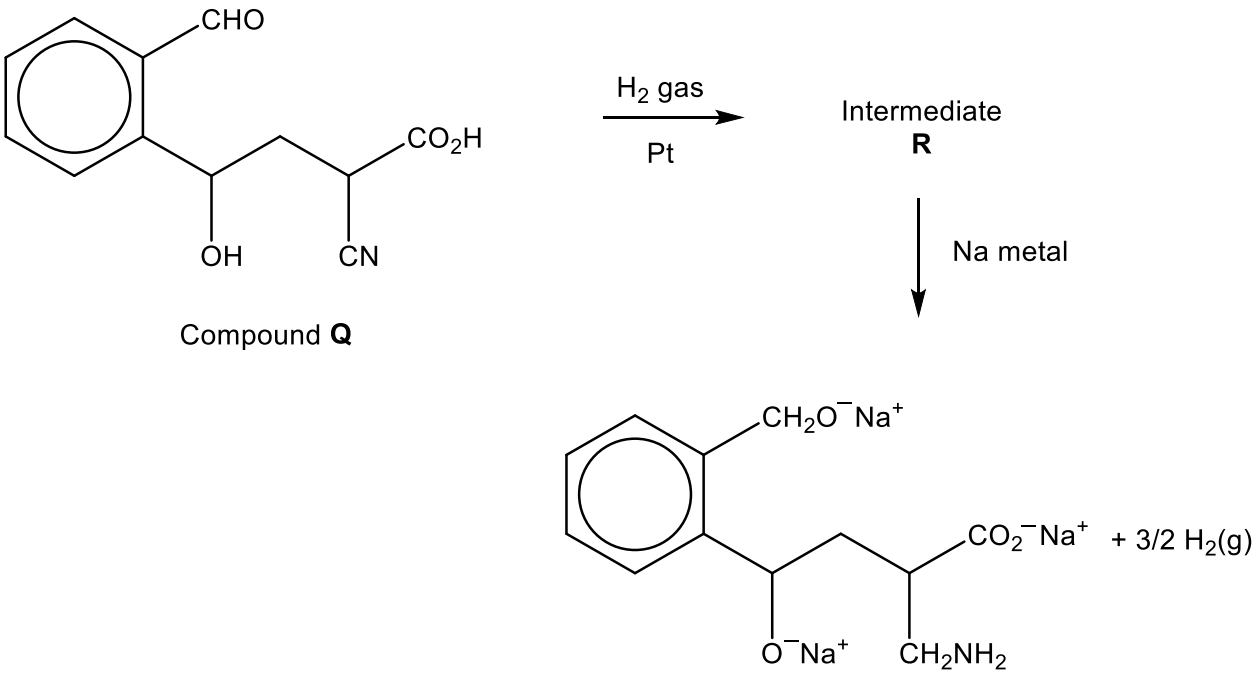
Concept: reactions and distinguishing tests relating to carbonyl compounds

Compound Z is a diketone.
Option A: Incorrect since there is no aldehyde functional group in compound Z and thus cannot give a silver mirror with Tollens' reagent.
Option B: Incorrect since ketone cannot undergo further oxidation.

Option C: Correct since it has  **group and thus able to give a yellow precipitate with alkaline aqueous iodine.**
Option D: Incorrect as ketone can undergo condensation with 2,4-DNPH to give an orange precipitate.

Answer: C

22 Compound **S** can be obtained via the following 2-step synthesis from compound **Q**.



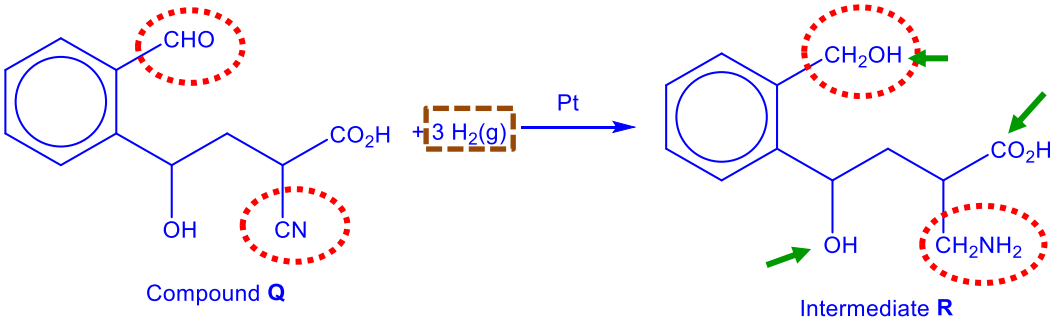
Compound **Q**

Compound **S**

If 96 dm^3 of hydrogen gas was reacted with **one mole** of compound **Q**, followed by the addition of sodium metal at room temperature and pressure, what is the final gas volume when the reaction was completed? (Given V_m = 24 dm^3 mol^{-1} at r.t.p.)

A Gas volume decreases by 36 dm^3.
B Gas volume decreases by 60 dm^3.
C Gas volume increases by 36 dm^3.
D No change in gas volume.

Topic: Carbonyl Compounds, Alcohols and Carboxylic Acids
Concept: Reduction of carbonyl compounds and nitriles, redox reaction of –OH group

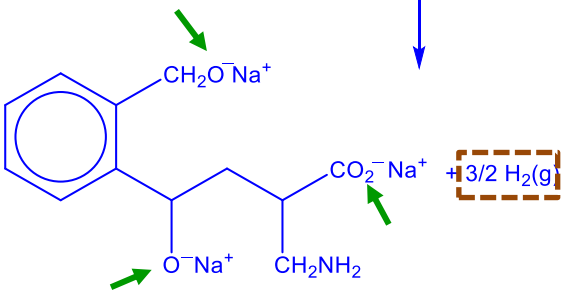


Compound **Q**

Intermediate **R**

H_2 gas with Pt will only reduce alkenes, carbonyl compounds and nitriles (note: ⬭)

Na metal will react with the –OH group in alcohols and carboxylic acids. (note: →)

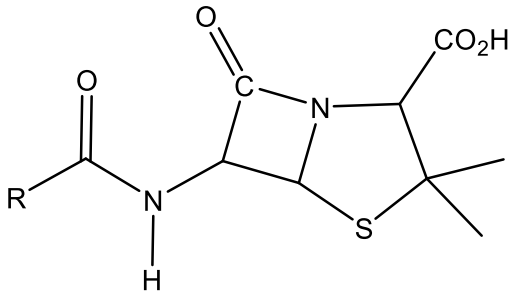


Compound **S**

3 mol of H_2 gas was used up for reduction while 1.5 mol of H_2 gas was produced from the redox reaction, hence more H_2 gas was consumed and there will be a decrease in gas volume.
Change in gas volume = 1.5 x 24 = 36 dm^3

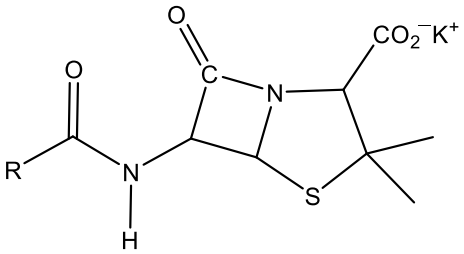
Answer: A

23 Penicillin is an antibiotic commonly used to treat a number of bacterial infections. The general structure of a penicillin molecule is given below.

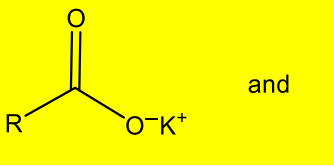


What are the products formed when penicillin is boiled with excess aqueous potassium hydroxide?

A



B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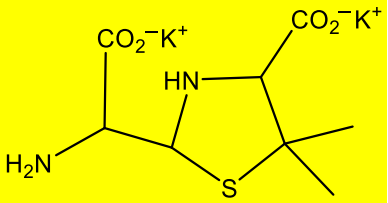
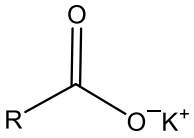


C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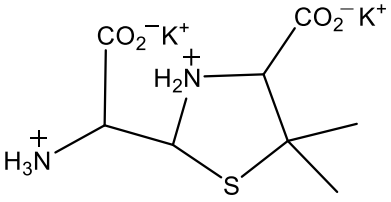
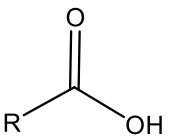
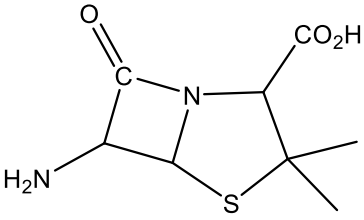
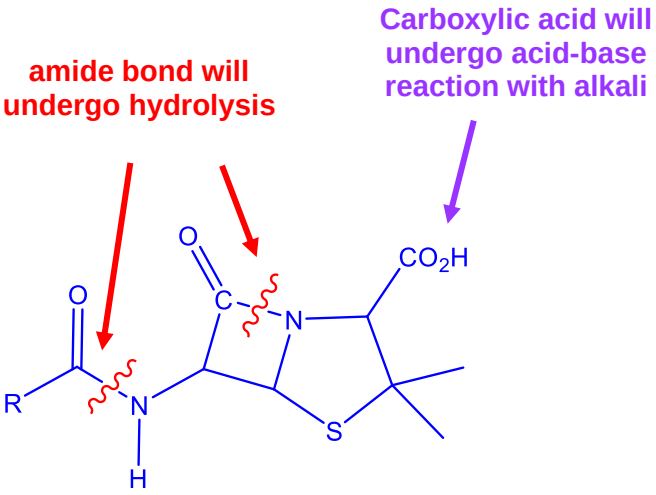


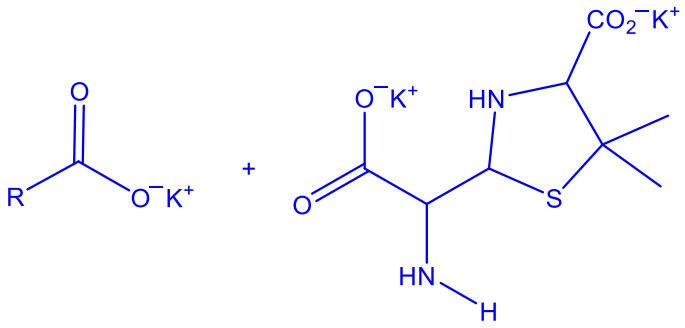
D


and


Topic: Nitrogen Compounds
Concept: Alkaline hydrolysis of amides

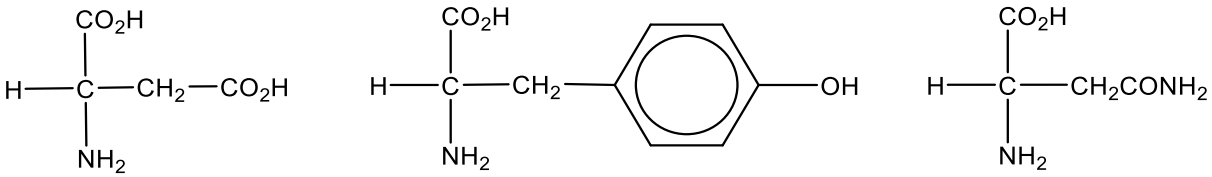


Hence, the hydrolysed products are:



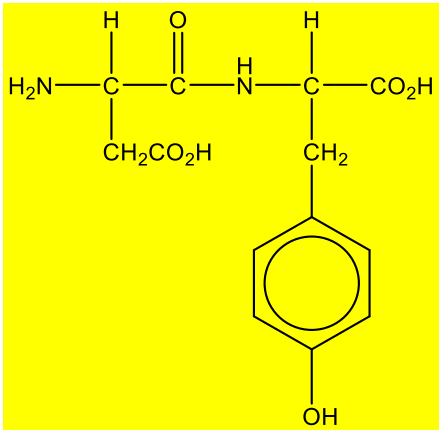
Answer: B

24 The following shows the structures of three amino acids.

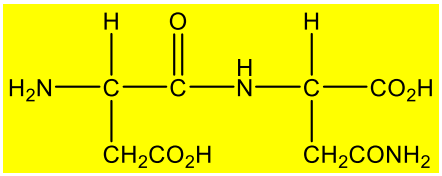


Which of the following represent the dipeptides formed from these amino acids?

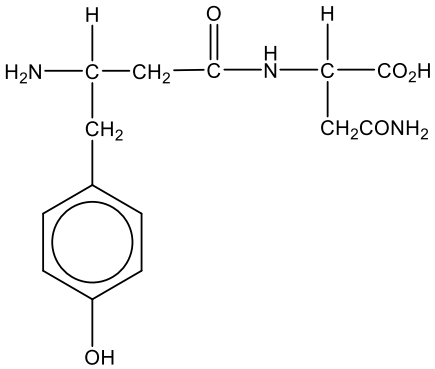
1



2



3

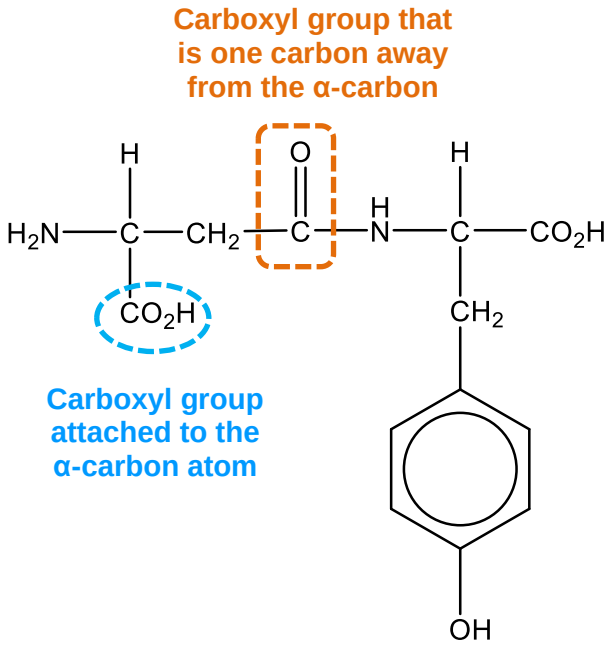


A 1, 2 and 3
B 1 and 2
C 1 and 3
D 2 only

Topic: Nitrogen Compounds
Concept: Formation of peptide bonds

Peptide bonds are formed between the carboxyl group (-CO_2H) of one amino acid with the amino (-NH_2) group of another amino acid. Both the carboxyl and amino groups are attached to the α-carbon atoms in the amino acids.

Option 3 is wrong because the carboxyl group in the first amino acid is not attached to the α-carbon atom.



Answer: B

25 Two electrode potentials are given.

$$Fe^{3+} + e^- \rightleftharpoons Fe^{2+} \qquad E^{\ominus} = +0.77\ V$$
$$Cl_2 + 2e^- \rightleftharpoons 2Cl^- \qquad E^{\ominus} = +1.36\ V$$

Which species is the strongest reducing agent?

A Fe^{3+} **B** Fe^{2+} **C** Cl_2 **D** Cl^-

Topic: Electrochemistry
Concept: Using $E^{\ominus}$ to determine strength of oxidising power.

A reducing agent reduces others and it gets oxidised (donates electrons).
The only 2 species undergoing oxidation are Fe^{2+} and Cl^-.
For the species ions to donate electrons, it must be more readily oxidised, i.e. less positive $E^{\ominus}$ value in the data booklet. Thus the only possible answer is B.

Answer: B

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

An electrochemical cell is set up using a $Fe^{2+}(aq)|Fe(s)$ half–cell and a $VO_2^+(aq),VO^{2+}(aq)|Pt(s)$ half–cell.

Which of the following gives a correct effect on the E_{cell} and a correct explanation for the effect when each of the changes is made to the cell separately?

	change	effect on E_{cell}	explanation
1	add KCN(aq) to the $Fe^{2+}(aq)|Fe(s)$ half–cell	increases	concentration of $Fe^{2+}(aq)$ decreases
2	add water to the $VO_2^+(aq),VO^{2+}(aq)|Pt(s)$ half–cell	decreases	concentration of water increases
3	increase temperature of the $Fe^{2+}(aq)|Fe(s)$ half–cell	no change	temperature change does not affect E_{cell}

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

Topic: Electrochemistry
Concept: Finding value of E_{cell} under non standard conditions

From the $E^{\ominus}$ in the *Data Booklet*,

$Fe^{2+} + 2e^- \rightleftharpoons Fe$ $\quad E^{\ominus} = -0.44$ V
$VO_2^+ + 2H^+ + e^- \rightleftharpoons VO^{2+} + H_2O$ $\quad E^{\ominus} = +1.00$ V

Fe^{2+}/Fe is the anode (–0.44V) while VO_2^+/VO^{2+} is the cathode (+1.00V).

$E^{\ominus}_{cell} = E^{\ominus}_{red} - E^{\ominus}_{oxid}$
$= (+1.00) - (-0.44)$
$= +1.44$ V

1: Adding KCN to Fe^{2+}/Fe half–cell will result in formation of $[Fe(CN)_6]^{4-}$ and hence cause $[Fe^{2+}]$ to decrease. $E_{Fe2+/Fe}$ will become more negative as its p.o.e. in equation 1 shifts to the left, hence E_{cell} will become more positive (increases).

$Fe^{2+} + 2e \rightleftharpoons Fe$ ---- 1
$Fe^{2+} + 6CN^- \rightleftharpoons [Fe(CN)_6]^{4-}$ ---- 2

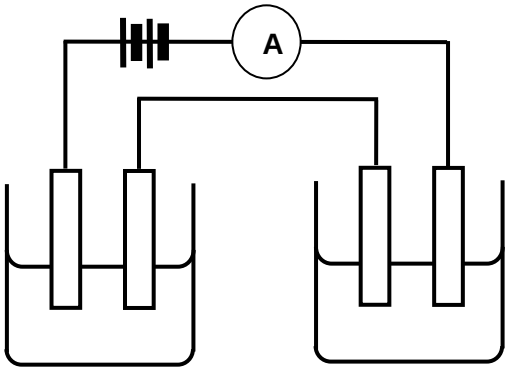
2: Adding water to VO_2^+/VO^{2+} half–cell will decrease both $[VO_2^+]$ and $[VO^{2+}]$. Its p.o.e. shifts to the left as there are more ions on the left. $E_{VO2+/VO2+}$ becomes less positive, hence E_{cell} will become less positive (decreases).
$VO_2^+ + 2H^+ + e \rightleftharpoons VO^{2+} + H_2O$
OR concentration of water remains unchanged.

3: E_{cell} changes with temperature unless ΔH of half–cell = 0

Answer: D

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

Using inert electrodes, a current was passed through two beakers containing aqueous silver sulfate and aqueous copper(II) nitrate, connected in series under standard conditions.



At 25^{o}C, 1 bar

What is the ratio of the mass of silver to copper deposited after the current was passed for *t* minutes?

A	0.59	**B**	0.85
C	1.70	**D**	3.40

Topic: Electrochemistry
Concept: Electrolysis

Relevant mole ratio: Cu ≡ 2e (from Cu^{2+}) and Ag ≡ e (from Ag^{+})

Since same current pass through in t minutes, same amount of electrons passed (notice this is INDEPENDENT of the initial concentrations of the solutions) to find mole ratio between Cu and Ag formed,
Cu ≡ 2e and 2Ag ≡ 2e so Cu ≡ 2Ag

Ratio of mass of Ag to mass of Cu = 2 x 107.9 : 63.5 = 3.40

Answer: D

28 A current of 10 A is passed for 150 minutes through molten aluminium oxide using inert electrodes.

What will be the approximate volume of gas liberated, measured at s.t.p.?

A 0.089 dm^3 **B** 5.3 dm^3 **C** 5.6 dm^3 **D** 11.2 dm^3

Topic: Electrochemistry
Concept: Electrolysis

Using Q = It,
Q = 10 x 150 x 60
= 90 000C
No. of Faradays = $\frac{90\,000}{9.65\times 10^4} = 0.9326$ **F**

In molten aluminium oxide, no water is present, so the oxygen gas liberated is from Al_2O_3. The oxide ion in Al_2O_3 is O^{2-}.

$2O^{2-} \longrightarrow O_2 + 4e^-$

Since $O_2 \equiv 4e$,

4 F liberates 1 mol of O_2 gas
0.9326 F liberates 0.2332 mol of O_2 gas

Vol of O_2 gas = 0.2332 x 22.7 dm^3 = 5.29 dm^3

Answer: B

29 $EDTA^{4-}(aq)$ solution is added dropwise until in excess to a solution of $[CrCl_2(H_2O)_4]^+$. The equlibrium constant for this reaction is greater than 1 and the equation for the reaction is as shown below.

$$[CrCl_2(H_2O)_4]^+(aq) + EDTA^{4-}(aq) \rightleftharpoons [Cr(EDTA)]^-(aq) + 2Cl^-(aq) + 4H_2O(l)$$

Which one of the following statements about the above reaction is correct?

A There is no change in colour of the solution after addition of $EDTA^{4-}$.

B $[Cr(EDTA)]^-$ is a less stable complex ion than $[CrCl_2(H_2O)_4]^+$.

C Both $[Cr(EDTA)]^-$ and $[CrCl_2(H_2O)_4]^+$ are octahedral complexes.

D The above is a redox reaction.

Topic: Transition Metals

Option A is incorrect:

The colour of a transition metal complex depends on the energy gap, ΔE. The energy gap, ΔE, in turn depends on the nature of the ligands.

Different ligands split the energy level of d orbitals to different extent.

⇒ Amount of energy, ΔE, absorbed by d electron in d-d transition differ.

⇒ Colour of transition metal complex solution would change with different ligands used.

⇒ There would be color of the solution will lighten after adding $EDTA^{4-}$.

Option B is incorrect:

It is given that the equilibrium constant for the above reaction is more than 1,

⇒ Concentration of $[Cr(EDTA)]^-$ > concentration of $[CrCl_2(H_2O)_4]^+$

⇒ $[Cr(EDTA)]^-$ is more stable than $[CrCl_2(H_2O)_4]^+$.

Option C is correct:

For $[CrCl_2(H_2O)_4]^+$, the central Cr^{3+} ion has 6 bond pairs. Hence, it is an octahedral complex.

$EDTA^{4-}$ is a hexadentate ligand that forms only six dative bonds with the central metal cation. Hence, the central Cr^{3+} ion in $[Cr(EDTA)]^-$ has 6 bond pairs. It is an octahedral complex.

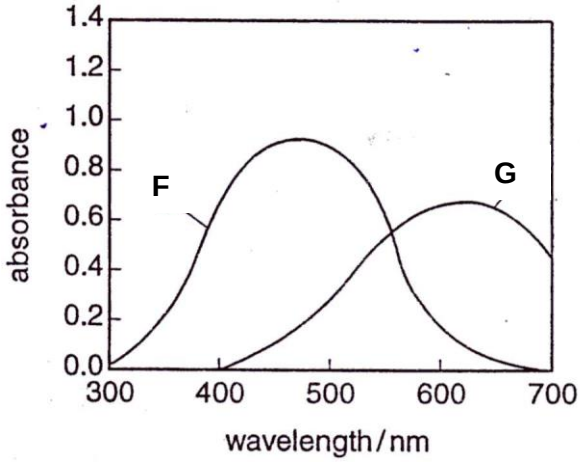
Option D is incorrect:

The above reaction does not involve any change in the oxidation no of the elements involved. Hence, it is not a redox reaction. Instead, it is a ligand exchange reaction.

Answer: C

30 The absorbance of a solution at a particular wavelength is proportional to the concentration of ion responsible for the absorption.

The visible spectra of solutions of two transition metal complexes **F** and **G** are shown in the diagram below. Both complexes contain the same transition metal ion.



Given that energy is inversely proportional to wavelength and the visible region of the electromagnetic spectrum is as follows:

violet	blue	green	yellow	orange	red
400		500		600	700

Wavelength (nm)

Which of following statements can be deduced from the spectra?

1 Complex **F** is likely to be red while complex **G** is likely to be blue.

2 The energy gap in complex **F** is greater than that in complex **G.**

3 The K_c value for the formation of complex **F** is higher than the K_c value for formation of complex **G**.

A 1, 2 and 3 are correct

B 1 and 2 only are correct

C 2 and 3 only are correct

D 1 only is correct

Topic: Transition Metals

Option 1 is correct as Complex F absorbed light of lower wavelength (green) and the complementary colour (red) is observed. Complex G absorbed light of higher wavelength (orange) and the complementary colour (blue) is observed.

Option 2 is correct as Complex F absorbed light of lower wavelength and thus ΔE is larger (since $\Delta E \propto 1/\lambda$) than that of Complex G. This means that the ligand in F is a stronger field ligand than that in complex G.

Option 3 is wrong as we cannot determine K_c value base on individual absorption curve. We can determine the magnitude of K_c value only if we are looking at a mixture absorption curve whereby there is equal amount of both ligands.

Ans: B