Class | Reg Number

Candidate's Name: _____

MERIDIAN JUNIOR COLLEGE
JC 1 Promotional Examination
Higher 2

Chemistry 9729

27 September 2017

Section A **40 minutes**

Additional Materials: OMR Sheet and *Data Booklet*

READ THESE INSTRUCTIONS FIRST

This booklet contains Section **A** of your paper.

Write your name, class and register number in the spaces provided at the top of this page.

There are **twenty** questions in this section. Answer **all** questions. For each question, there are four possible answers labelled **A**, **B**, **C** and **D**. Choose the **one** you consider correct and record your choice in soft pencil on the OMR answer sheet.

Read very carefully the instructions on the use of OMR answer sheet.

You are advised to fill in the OMR Answer Sheet as you go along; no additional time will be given for the transfer of answers once the examination has ended.

Use of OMR Answer Sheet

Ensure you have written your name, class register number and class on the OMR Answer Sheet.

Use a **2B** pencil to shade your answers on the OMR sheet; erase any mistakes cleanly. Multiple shaded answers to a question will not be accepted.

For shading of class register number on the ***OMR sheet***, please follow the given examples:

If your register number is **1**, then shade **01** in the index number column.
If your register number is **21**, then shade **21** in the index number column.

Answer all questions in this section.

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

1 Methylamine, CH_3NH_2, is a colourless gas which has a strong odour similar to fish. It burns in oxygen according to the following equation.

$$CH_3NH_2\,(g) + \frac{13}{4}O_2\,(g) \longrightarrow CO_2\,(g) + NO_2\,(g) + \frac{5}{2}H_2O\,(l)$$

A sample of 10 cm^3 of methylamine was burned in 50 cm^3 of oxygen. The products were cooled to room temperature and treated with an excess of aqueous sodium hydroxide.

What would be the final volume of the resultant mixture of gases?

A 17.5 cm^3 **B** 20.0 cm^3 **C** 27.5 cm^3 **D** 37.5 cm^3

Answer: A

Suggested Solution:

	$CH_3NH_2(g)$ +	$\frac{13}{4}O_2(g)$ ⟶	$CO_2(g)$ +	$NO_2(g)$ +	$\frac{5}{2}H_2O(l)$
Initial volume	10	50	0	0	–
Change in volume	–10	–32.5	+10	+10	–
Final volume	0	17.5	10	10	–

CO_2 and NO_2 are acidic. Hence, both of them reacted with aqueous NaOH when the product was passed through a solution of sodium hydroxide.

Final volume = volume of unreacted O_2 = **17.5 cm^3**

2 How many atoms are present in 24 cm^3 of carbon dioxide gas under room conditions?

A $\frac{6.02 \times 10^{23}}{10^3}$ B $\frac{3 \times 6.02 \times 10^{23}}{10^3}$

C $\frac{3 \times 6.02 \times 10^{23}}{24000}$ D $3 \times 24 \times 6.02 \times 10^{23}$

Answer: B

Suggested Solution:

Amount of $CO_2 = \frac{24}{24000}$ mol

$CO_2 \equiv 2O \equiv C$; → 3 atoms in one molecule of CO_2

Amount of atoms = $\frac{24}{24000} \times 3$ mol

Number of atoms in 24 cm^3 of $CO_2 = \frac{3 \times 24 \times 6.02 \times 10^{23}}{24000}$

3 25.0 cm^3 of 0.05 mol dm^{-3} acidified NH_4VO_3 was reduced by sulfur dioxide to form a deep–blue solution containing V^{n+} ions.

The V^{n+} ions are then re–oxidised to its original oxidation state by 12.50 cm^3 of 0.02 mol dm^{-3} acidified $KMnO_4$.

What is the oxidation state of vanadium in the deep–blue solution?

A 0 B +3 C +4 D +6

Answer: C

Suggested Solution:

Amount of VO_3^- used = $0.05 \times \frac{25.0}{1000} = 1.25 \times 10^{-3}$ mol

Amount of V^{n+} formed = 1.25×10^{-3} mol

Amount of MnO_4^- used = $0.02 \times \frac{12.50}{1000} = 2.50 \times 10^{-4}$ mol

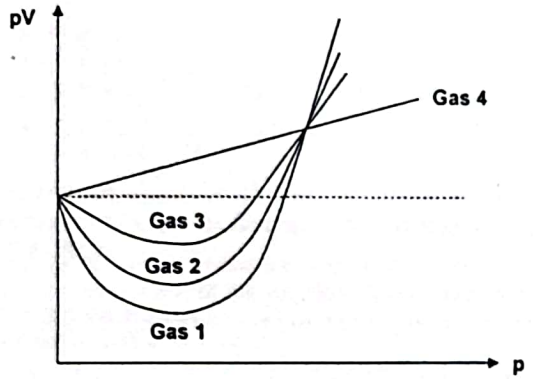
From the calculations, 2.50×10^{-4} mol $MnO_4^- \equiv 1.25 \times 10^{-3}$ mol V^{n+}
1 $MnO_4^- \equiv 5\ V^{n+} \equiv 5e$

$MnO_4^- + 8H^+ + 5e \longrightarrow Mn^{2+} + 4H_2O$
1 mol of MnO_4^- gains 5 mol of electrons
5 mol of V^{n+} loses 5 mol of electrons to form back VO_3^-

1 mol of V^{n+} loses 1 mol of electron hence oxidation state increases by 1 unit from +n in V^{n+} to +5 in VO_3^-

Hence, the oxidation state of vanadium in V^{n+} of deep-blue solution = **+4**

4 The value of pV is plotted against p at the same temperature for four gases, where p is the pressure and V is the volume of the gas.



Which of the following statements are correct?

1 All gases deviate most from ideal gas behaviour at high pressures.

2 The intermolecular forces of attraction in Gas **3** is more significant than that in Gas **2**.

3 Gas **1** is H_2O; Gas **2** is HF; Gas **3** is CH_3F; Gas **4** is Ne.

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

Answer: C (Statement 1 and 3 are correct)

Suggested Solution:

Statement 1: At high pressure, the gas particles come close together, volume occupied by the gas particles becomes significant as compared to the volume of the container.

Statement 2: From the sketch, the Gas **2** deviates more from ideal gas behaviour as compared to Gas **3** hence one can infer that intermolecular forces of attractions between the gas particles are more significant in Gas **2** compared to Gas **3**.

Statement 3: The more significant the intermolecular forces of attractions between the gas particles, the larger the deviation from ideal gas behaviour.

Gas	Predominant type of intermolecular forces of attraction
H_2O	Hydrogen bonding between H_2O molecules H_2O forms 2 hydrogen bonds per molecule
HF	Hydrogen bonding between HF molecules HF forms 1 hydrogen bond per molecule
CH_3F	Permanent dipole–permanent dipole attractions between CH_3F molecules
Ne	Instantaneous dipole–induced dipole attractions between Ne atoms

Strength of forces of attraction: hydrogen bonding > permanent dipole–permanent dipole > instantaneous dipole–induced dipole

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

The ion X^{4+} contains 28 electrons and 42 neutrons.

Which of the following statements about X^{4+} or X^{2+} is correct?

A X^{2+} has less protons than $^{59}Co^{2+}$.

B X^{4+} has the same electronic configuration as $^{58}Ni^{2+}$.

C X^{4+} has the same nucleon number as $^{75}As^{3+}$.

D X^{2+} has a lower tendency to form covalent compounds than X^{4+}.

Answer: D

Suggested Solution:

Statement A is incorrect.
X^{4+} contains 28 + 4 = 32 protons. So X^{2+} also has 32 protons.
$^{59}Co^{2+}$ has 27 protons.

Statement B is incorrect.
X^{4+} contains 28 electrons.
Electronic configuration of X^{4+}: [Ar] $3d^{10}$
For Ni^{2+} (26 electrons), Electronic configuration of Ni^{2+}: [Ar] $3d^{8}$

Statement C is incorrect.
X^{4+} contains 28 + 4 = 32 protons and 42 neutrons.
X^{4+} nucleon number = 32 + 42 = 74
$^{75}As^{3+}$ nucleon number is 75

Statement D is correct.
X^{2+} has a smaller charge density than X^{4+} thus it is less able to polarise the anion charge cloud, thus has less tendency to induce covalent character in its compounds.

6 The angle of deflection of a beam of $^{27}_{13}Al^{3+}$ in an electric field is +5.6 °.

What is a possible species that will give an angle of deflection of 4.2 ° when passed through the same electric field?

A $^{19}_{9}F^{-}$ B $^{24}_{12}Mg^{2+}$ C $^{32}_{16}S^{2-}$ D $^{52}_{24}Cr^{2+}$

Answer: B

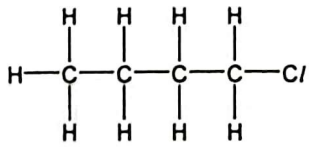
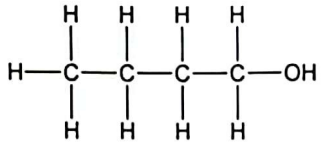
Suggested Solutions

$\frac{q}{m}$ ratio for $^{27}_{13}Al^{3+} = +\frac{3}{27} = +\frac{1}{9}$ → 5.6 °

If angle of deflection is 4.2 °, then $\frac{q}{m}$ ratio for unknown species = $\frac{4.2}{5.6} \times \frac{1}{9} = 0.0833$

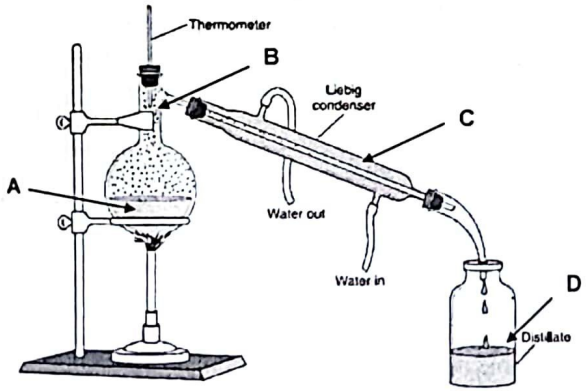
species	$^{19}_{9}F^{-}$	$^{24}_{12}Mg^{2+}$	$^{32}_{16}S^{2-}$	$^{52}_{24}Cr^{2+}$
$\frac{q}{m}$	$\frac{1}{19} = 0.0526$	$\frac{2}{24} = 0.0833$	$\frac{2}{32} = 0.0625$	$\frac{2}{52} = 0.0385$

7 1–chlorobutane can be synthesised by reacting butan–1–ol with thionyl chloride, $SOCl_2$.

1–chlorobutane	butan–1–ol
	

Distillation is performed to separate the 1–chlorobutane and the unreacted butan–1–ol upon completion of the reaction. A distillation set–up is shown below where the organic compound with the lower boiling point will distil out first.

Which region indicates an area where there is a higher proportion of butan–1–ol than 1–chlorobutane?



Answer: A

Suggested Solution:

Concept:
The higher boiling point compound will distil out last hence higher proportion will remain in the round bottom flask.

Hydrogen bonding between butan–1–ol molecules is stronger than the permanent dipole–permanent dipole attraction between 1–chlorobutane molecules.

Boiling point of butan–1–ol (117.7 °C) > 1–chlorobutane (78 °C).
Higher proportion of butan–1–ol will be in the round bottom flask.

8 The melting points of two aluminium halides, AlX_3 are given below.

Compound	Formula	Melting Point/ °C
Aluminium fluoride	AlF_3	1291
Aluminium chloride	$AlCl_3$	178

Which pairs of factors provide the reasons to explain for the differences in the melting points?

1 charge density of cation
2 radius of anion
3 strength of the Al–X bond
4 distortion of electron cloud

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

Answer: D

Suggested Solution:

In both compounds, the cation, Al^{3+} is the same → hence charge density of cation is identical.

$AlCl_3$	AlF_3
Al^{3+} has a high charge density hence it is able to polarise the large Cl^- anion electron cloud to such a large extent that the Al–Cl bonds become covalent.	Even though the charge density of Al^{3+} is high but the small anion F^- is not easily polarisable. Hence, AlF_3 remains giant ionic in nature.

9 Nickel is a by–product formed by a series of changes in which the rate–determining step is the radioactive decay of cobalt–60, a radiation source for cancer treatment. This radioactive decay is a first–order reaction with a half–life of 5.3 years.

How long would it take for a radiation cartridge of cobalt–60, originally nickel–free, to contain a molar proportion of cobalt to nickel of 1:7?

A 0.8 years
B 14.9 years
C 15.9 years
D 37.1 years

Answer: C

Suggested Solution:

Let amount of Co in the cartridge be x.

$$x \xrightarrow{t_{\frac{1}{2}}} \frac{1}{2}x \xrightarrow{t_{\frac{1}{2}}} \frac{1}{4}x \xrightarrow{t_{\frac{1}{2}}} \frac{1}{8}x$$

Hence, maximum amount of Ni that can be formed in the cartridge = x.

$$0 \xrightarrow{t_{\frac{1}{2}}} \frac{1}{2}x \xrightarrow{t_{\frac{1}{2}}} \frac{3}{4}x \xrightarrow{t_{\frac{1}{2}}} \frac{7}{8}x$$

OR $\dfrac{\text{Amount of Co at time t}}{\text{Initial amount of Co}} = \left(\dfrac{1}{2}\right)^n \Rightarrow \dfrac{1}{(1+7)} = \left(\dfrac{1}{2}\right)^n \Rightarrow n = 3$

After 3 half–lives, $\frac{7}{8}x$ of Co would be converted into Ni

⇒ Molar proportion of Co : Ni = 1:7 after **15.9 years (3 × 5.3 years)**

10 The reaction between nitrogen monoxide, NO and oxygen, O_2 takes place as follows:

$$2NO \rightleftharpoons N_2O_2 \quad \text{(fast)}$$
$$N_2O_2 + O_2 \longrightarrow 2NO_2 \quad \text{(slow)}$$

Which of the following statement is correct?

A The overall reaction is third order.
B The reaction is an elementary reaction.
C The rate equation is Rate = $k\,[N_2O_2]\,[O_2]$.
D The activation energy of the first step is higher than the second step.

Answer: A

Suggested Solution:

Consider by elimination

Option **A** is correct; the rate equation is based on the slow step should be: Rate = $k[NO]^2[O_2]$, overall order = 2 + 1 = **3**

By steady–state approximation of first step, $K_c = \dfrac{[N_2O_2]}{[NO]^2} \Rightarrow [N_2O_2] = K_c[NO]^2$

Hence from rate–determining second step: Rate = $k[N_2O_2][O_2] \Rightarrow$ Rate = $k[NO]^2[O_2]$, where $k = k' \times K_c$

Option **B** is incorrect as there are more than 1 step in the reaction, i.e. non–elementary reaction.

Option **C** is incorrect; N_2O_2 is an intermediate and does not feature in the rate equation.

Option **D** is incorrect as the second step is the slow step, which has the higher activation energy; first step has a lower activation energy.

11 A 0.0113 mol sample of ammonium nitrate is introduced into an evacuated vessel with a volume of 0.83 dm^3. The vessel, of constant volume, is heated to a constant temperature such that the equilibrium below is established.

$$NH_4NO_3\,(s) \rightleftharpoons NH_3\,(g) + HNO_3\,(g)$$

Given that the percentage dissociation of ammonium nitrate at equilibrium is 66.8%, what is the value of the equilibrium constant, K_c?

A 5.70×10^{-5} B 8.27×10^{-5}
C 0.0152 D 0.0183

Answer: B

Suggested Solutions:

At equilibrium,

$[NH_3] = [HNO_3]$

$$= \frac{0.0113}{0.83} \times \frac{66.8}{100}$$

$= 0.00909$ mol dm^{-3}

$K_c = [NH_3][HNO_3]$

$= (0.00909)\,(0.00909)$

$= 8.27 \times 10^{-5}$ mol^2 dm^{-6}

12 The key stage in the manufacture of sulfuric acid is the reaction between sulfur dioxide and oxygen.

$$2SO_2\,(g) + O_2\,(g) \rightleftharpoons 2SO_3\,(g) \qquad \Delta H = -197\ kJ\ mol^{-1}$$

Which of the following statements are correct for an increase in temperature?

1 The equilibrium constant increases.
2 The rate constant for the forward reaction increases.
3 The rate constant for the backward reaction increases.
4 The activation energy for the forward reaction decreases.

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

Answer: C (Statements 2 and 3 are correct)

Suggested Solutions:

1 Statement 1 is incorrect.
By Le Chatelier's Principle, the equilibrium position shifts left towards the endothermic reaction to absorb heat when temperature increases.
Hence, there are more reactants and less products present at the new equilibrium,
Hence, the equilibrium constant decreases.

2 Statement 2 is correct.
The rate constant for the forward reaction increases as temperature increases.
Arrhenius equation: $k = Ae^{\frac{E_a}{RT}}$; rate constant of a reaction increases with an increase in temperature.

3 Statement 3 is correct.
The rate constant for the backward reaction increases as temperature increases.
Arrhenius equation: $k = Ae^{\frac{E_a}{RT}}$; rate constant of a reaction increases with an increase in temperature.

4 Statement 4 is incorrect.
The activation energy for the forward reaction do not change with temperature (activation energy only decreases when catalyst is introduced).

13 The dihydrogen phosphate ion, $H_2PO_4^-$ can act as a base or an acid.

$$H_2PO_4^- + H_2CO_3 \rightleftharpoons H_3PO_4 + HCO_3^- \qquad K_c < 1$$
$$H_2PO_4^- + HCO_3^- \rightleftharpoons HPO_4^{2-} + H_2CO_3$$

The conjugate _____ of $H_2PO_4^-$ is _____, and H_3PO_4 is a stronger acid than _____.

A acid; HPO_4^{2-}; H_2CO_3

B acid; H_3PO_4; HCO_3^-

C base; HPO_4^{2-}; HPO_4^{2-}

D base; HPO_4^{2-}; H_2CO_3

Answer: D

Suggested Solution:

The conjugate acid of $H_2PO_4^-$ is H_3PO_4.
The conjugate base of $H_2PO_4^-$ is HPO_4^{2-}.

Since $K_c < 1$ for first equilibrium, backward reaction is favoured and H_3PO_4 is stronger acid than H_2CO_3.

14 Values for the ionic product of water, K_w, at two different temperatures are given below.

Temperature / °C	K_w / mol² dm⁻⁶
10	2.90×10^{-15}
25	1.00×10^{-14}

What is correct for pure water at 10 °C?

A pH = 7

B pH > 7

C $[H^+] = 2.90 \times 10^{-8}$ mol dm^{-3}

D $[H^+] > [OH^-]$

Answer: B

Suggested Solution:

At 10 °C, $K_w = [H^+]\,[OH^-] = 2.90 \times 10^{-15}$
$[H^+] = [OH^-] = \sqrt{(2.90 \times 10^{-15})} = 5.39 \times 10^{-8}$ mol dm^{-3}. Statement C is incorrect.

pH = –lg (0.539×10^{-7}) = 7.27; Statement B is correct and Statement A is incorrect.

$H_2O \rightleftharpoons H^+ + OH^-$
For pure water, $[H^+] = [OH^-]$; Statement D is incorrect.

15 A mixture is made by mixing equal volumes of a solution of H_2SO_4 (aq) of pH 2 and of a solution of HCl (aq) of pH 3.

What is the pH of the resulting solution?

A 1.67 B 1.96 C 2.26 D 2.50

Answer: C

Suggested Solution

Equal volumes of each solution mixed → $[H^+]$ contributed by each acid is halved.

$[H^+]$ in $H_2SO_4 = \frac{10^{-2}}{2} = 0.005$ mol dm^{-3}

$[H^+]$ in HCl $= \frac{10^{-3}}{2} = 0.0005$ mol dm^{-3}

Total $[H^+] = 0.005 + 0.0005 = 0.0055$ mol dm^{-3}

pH = –lg 0.0055 = **2.26**

16 The values of the solubility products at 25 °C of three metal sulfides are tabulated below.

Compound	Value of solubility product
CuS	8.5×10^{-45}
Ag_2S	1.6×10^{-49}
Bi_2S_3	1.1×10^{-73}

The dissolution process of these metal sulfides is endothermic.

Which statements about the metal sulfides are correct?

1 The value of the solubility products of the metal sulfides increases with temperature.
2 The value of the solubility products of the metal sulfides decreases when there is a common ion effect as the solubility decreases.
3 The molar solubility of the metal sulfides decreases in the following order: $CuS > Ag_2S > Bi_2S_3$.
4 The molar solubility of the metal sulfides increases when pH decreases.

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

Answer: B (Statement 1 and 4 are correct)

Suggested Solution:

Statement 1 is correct since when temperature increases, forward endothermic dissolution reaction is favoured, the equilibrium concentrations of ions increases and hence K_{sp} value increases.

Statement 2 is wrong since K_{sp} value is only temperature–dependent.

Statement 3 is wrong as solubility decreases in the order of $Bi_2S_3 > Ag_2S > CuS$.
For CuS: $8.5 \times 10^{-45} = s.s = s^2$ $\Rightarrow s = 9.22 \times 10^{-23}$ mol dm^{-3}
For Ag_2S: $1.6 \times 10^{-49} = (2s)^2.s = 4s^3$ $\Rightarrow s = 3.42 \times 10^{-17}$ mol dm^{-3}
For Bi_2S_3: $1.1 \times 10^{-73} = (2s)^2(3s)^3 = 108s^5$ $\Rightarrow s = 1.00 \times 10^{-15}$ mol dm^{-3}

Statement 4 is correct.
When pH decreases (i.e. concentration of H^+ increases), concentration of S^{2-} decreases since the H^+ will react with S^{2-} to form H_2S molecule. Hence, the equilibrium position of the solubility equilibria of the metal sulfides will shift right resulting in more solid dissolving.

17 Cyanopropyne has the following structure:

$CH_3C{\equiv}CCN$

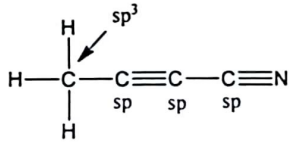
Which statements about the molecule are correct?

1 There are 6 sigma bonds and 2 pi bonds.
2 All the carbon atoms lie in the same plane.
3 Only two of the carbon atoms are *sp* hybridised.
4 One of the terminal carbon atoms has a tetrahedral geometry.

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

Answer: C **(Statement 2 and 4 are correct)**

Suggested Solution:



The bond between C and N is a triple bond.

Statement 1 is wrong since there are 7 σ and 4 π bonds.

Statement 2 is correct as the C atoms are arranged in a linear fashion; C≡C carbons are *sp* hybridised (linear).

Statement 3 is wrong. There are 3 carbon atoms which are *sp* hybridised.

Statement 4 is correct. Only the CH_3 carbon atom is sp^3 hybridised and hence tetrahedral.

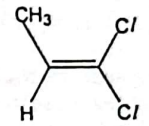
18 How many constitutional and *cis–trans* isomers are there for dichloropropene, $C_3H_4Cl_2$?

A 5 B 6 C 7 D 8

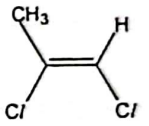
Answer: C

Suggested Solution:

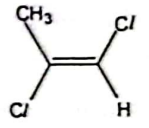
The 7 constitutional and cis-trans isomers are:



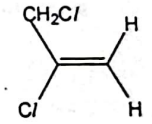
1,1-dichloropropene



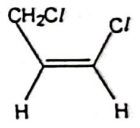
cis-1,2-dichloropropene



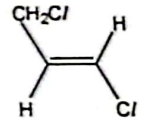
trans-1,2-dichloropropene



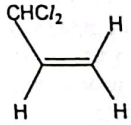
2,3-dichloropropene



Z-1,3-dichloropropene

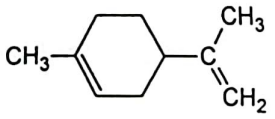


E-1,3-dichloropropene



3,3-dichloropropene

19 Limonene is an oil formed in the peel of citrus fruits.



limonene

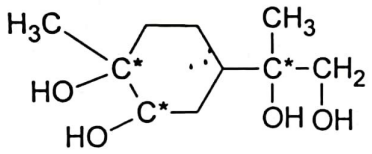
When limonene reacts with excess cold dilute $KMnO_4$, how many **more** chiral centres than limonene does the product possess?

A 2 B 3 C 4 D 5

Answer: B

Suggested Solution:

The 3 additional chiral centres, C* in the oxidation product are as shown:



20 Which two–stage process will give the greatest yield of $CH_2(Br)CH(Br)CH_2CH_3$?

A $CH_3CH(Br)CH_2CH_3$ —ethanolic KOH, heat→ —Br_2 in organic solvent→

B $CH_2=CHCH_2CH_3$ —HBr→ —limited Br_2, heat→

C $CH_3CH=CHCH_3$ —H_2 (g), Pt→ —Br_2 (g), uv light→

D $CH_3CH_2CH_2CH_2OH$ —conc. H_2SO_4, 170°C→ —Br_2 in organic solvent→

Answer: D

Suggested Solution:

A: 2–bromobutane undergoes elimination with ethanolic KOH to form two products, but–2–ene (major product) and but–1–ene (minor). To get the desired product 1,2-dibrombutane in high yield, but-1-ene must be obtained in high yield in Step 1 before re but-1-ene with Br_2 in organic solvent. Hence, synthetic pathway A is not ideal.

B: but–1–ene undergoes electrophilic addition to form 2–bromobutane (major product) and 1–bromobutane (minor product). In stage 2, the free radical substitution reaction yields many different products. Hence, the yield of 1,2-dibrombutane will not be ideal.

C: but–2–ene undergoes reduction with H_2 (g) to form butane. In stage 2, butane undergoes free radical substitution to form many different products. Hence, the yield of 1,2-dibrombutane will not be ideal.

D: butan–1–ol undergoes elimination with conc. H_2SO_4 to form but–1–ene. In stage 2, but–1–ene undergoes electrophilic addition to form 1,2–dibromobutane, producing 1,2-dibrombutane in high yield,

END OF SECTION A

Qn	1	2	3	4	5	6	7	8	9	10
Ans	A	B	C	C	D	B	A	D	C	A

Qn	11	12	13	14	15	16	17	18	19	20
Ans	B	C	D	B	C	B	C	C	B	D