# CHEMISTRY (CODE – 043)

## Chapter-wise Test: Alcohols, Phenols and Ethers

(NCERT Class XII Chemistry, Unit 7: Alcohols, Phenols and Ethers)

## SOLUTIONS AND MARKING SCHEME

## CLASS XII (2026-27)

**Time: 1½ hours** **Max. Marks: 35**

Step-by-step solutions with the distribution of marks. Marks for each step are shown in square brackets [ ]. Any other correct method or answer should be given full credit.

**Quick answer key – Section A**

| Q. | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 |
|---|---|---|---|---|---|---|---|---|
| Ans. | C | B | D | A | C | B | A | D |

### SECTION A

Questions 1 to 8 are multiple choice questions. Only one of the choices is correct. Select and write the correct choice as well as the answer to these questions. Each question carries 1 mark.

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| **1** | **Answer: C**<br>The parent chain is the longest chain carrying the –OH group, numbered from the end nearest to –OH (so –OH gets locant 1): pentan-1-ol. The substituents are then $CH_3$ at C-2 and C-3 and Cl at C-4: **4-chloro-2,3-dimethylpentan-1-ol**. | 1 |
| **2** | **Answer: B. Row 2**<br>$HOCH_2CH_2OH$, ethane-1,2-diol, is commonly called **ethylene glycol**; glycerol is propane-1,2,3-triol. The names in rows 1, 3 and 4 are correct. | 1 |
| **3** | **Answer: D**<br>Butan-1-ol (390 K) has an –OH group, so its molecules are held together by intermolecular hydrogen bonds. Ethoxyethane (307.6 K) has no O–H bond and cannot form hydrogen bonds with itself, and n-pentane (309.1 K) is non-polar, so their boiling points are low and nearly equal. The molecular masses are almost the same (72, 74, 74), so A and C do not explain the large difference, and the weak polarity of the ether C–O bond does not appreciably raise its boiling point. | 1 |
| **4** | **Answer: A. propan-1-ol**<br>In hydroboration the boron atom attaches to the $sp^2$ carbon carrying more hydrogen atoms (the terminal $CH_2$), so the –OH ends up on the terminal carbon: the net result is addition of water against Markovnikov's rule, giving the primary alcohol propan-1-ol. (Acid-catalysed hydration of propene gives propan-2-ol.) | 1 |
| **5** | **Answer: C**<br>Alcohols are weaker acids than water (the alkyl group is electron releasing and the alkoxide ion is a stronger base than $OH^-$). Phenol is a stronger acid than water and alcohols because the phenoxide ion is stabilised by delocalisation of the negative charge. An electron withdrawing $–NO_2$ group at the para position increases the acidity further ($pK_a$ 7.1 against 10.0 for phenol). Order: ethanol < water < phenol < *p*-nitrophenol. | 1 |
| **6** | **Answer: B. salicylaldehyde**<br>This is the Reimer–Tiemann reaction: a –CHO group is introduced at the ortho position of phenol through the intermediate substituted benzal chloride, which is hydrolysed by alkali to *o*-hydroxybenzaldehyde (salicylaldehyde). Salicylic acid is the product of Kolbe's reaction (NaOH, $CO_2$), and picric acid is formed with concentrated $HNO_3$. | 1 |

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| **7** | **Answer: A. phenol and methyl iodide**<br>The ether is first protonated. $I^-$ then attacks the $CH_3$ group by $S_N2$: the O–$CH_3$ bond is weaker than the O–$C_6H_5$ bond, because the carbon of the phenyl group is $sp^2$ hybridised and the bond has partial double bond character. Hence $C_6H_5OH + CH_3I$ are formed; phenol does not react further to give iodobenzene since $sp^2$ carbon cannot undergo nucleophilic substitution. | 1 |
| **8** | **Answer: D. A is false but R is true.**<br>Alcohols are weaker acids than water: the electron releasing alkyl group increases the electron density on oxygen and decreases the polarity of the O–H bond. The reaction $RO^- + H_2O \rightarrow ROH + OH^-$ shows that water is a better proton donor, and that the alkoxide ion is a stronger base than $OH^-$ (e.g. sodium ethoxide is a stronger base than NaOH). So A is false and R is true. | 1 |

## SECTION B

Question Nos. 9 to 11 are very short answer questions carrying 2 marks each.

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| **9** | **(A)**<br>(i) P is a **tertiary** alcohol, Q is **secondary**, R is **primary**. P = $(CH_3)_3C$–OH (2-methylpropan-2-ol). [1]<br>(ii) The reaction of an alcohol with HCl/$ZnCl_2$ proceeds through a carbocation; the tertiary carbocation is the most stable and forms fastest, so the insoluble alkyl halide (turbidity) appears immediately: 3° > 2° > 1°. [1]<br>**(B)**<br>(i) *n*-Butane < ethoxyethane < pentanal < pentan-1-ol (pentan-1-ol has intermolecular hydrogen bonding; the aldehyde is polar; ether weakly polar; butane non-polar). [1]<br>(ii) Ethanol < propan-1-ol < butan-2-ol < butan-1-ol (boiling point increases with the number of carbon atoms and decreases with branching). [1] | 1 + 1 |
| **10** | **(A)**<br>(i) $CH_3CH{=}CH_2 + H_2O \rightarrow (H^+$, dil. $H_2SO_4)$ $CH_3CH(OH)CH_3$ (acid-catalysed hydration; Markovnikov's rule). [1]<br>(ii) $3CH_3CH{=}CH_2 + (BH_3)_2 \rightarrow (CH_3CH_2CH_2)_3B \rightarrow (H_2O_2$, NaOH) $3CH_3CH_2CH_2OH$ (hydroboration–oxidation; anti-Markovnikov). [1]<br>**(B)**<br>(i) $HCHO + CH_3MgBr \rightarrow CH_3CH_2OMgBr \rightarrow (H_2O)$ $CH_3CH_2OH$ (methanal gives a primary alcohol). [1]<br>(ii) $CH_3COCH_3 + CH_3MgBr \rightarrow (CH_3)_3C$–OMgBr $\rightarrow (H_2O)$ $(CH_3)_3C$–OH (a ketone gives a tertiary alcohol). [1] | 1 + 1 |
| **11** | **(A)**<br>(i) In the body methanol is oxidised first to methanal (HCHO) and then to methanoic acid, which can cause blindness and death. [1]<br>(ii) The patient is given intravenous infusions of diluted ethanol. The enzyme that oxidises the aldehyde (HCHO) to the acid is swamped by ethanol, allowing time for the kidneys to excrete the methanol. [1]<br>**(B)**<br>(i) Commercial alcohol is made unfit for drinking by mixing in some copper sulphate (colour) and pyridine (a foul-smelling liquid): this is denaturation. [1]<br>(ii) Invertase (converts sucrose to glucose and fructose) and zymase (converts glucose and fructose to ethanol and $CO_2$). [1] | 1 + 1 |

| SECTION C | | |
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| Question Nos. 12 to 15 are short answer questions carrying 3 marks each. | | |
| **12** | **(A)**<br>(i) **P = ethene** ($CH_2=CH_2$, intramolecular dehydration); **Q = ethoxyethane** ($C_2H_5OC_2H_5$, intermolecular dehydration). [1]<br>(ii) **R = propanone** ($CH_3COCH_3$, dehydrogenation of the secondary alcohol); **S = 2-methylpropene** ($(CH_3)_2C=CH_2$), because tertiary alcohols undergo dehydration (not dehydrogenation) over Cu at 573 K. [1]<br>(iii) Tertiary > secondary > primary. The slow step is the formation of the carbocation, and tertiary carbocations are the most stable and therefore easiest to form. [1]<br>**(B)**<br>(i) Propanal, $CH_3CH_2CHO$ (PCC stops at the aldehyde stage). [1]<br>(ii) *p*-Benzoquinone (a conjugated diketone). [1]<br>(iii) Benzene, $C_6H_6$ (+ ZnO). [1] | 1 + 1 + 1 |
| **13** | **(A)**<br>(i) A = ***o*-nitrophenol** (2-nitrophenol), with **intramolecular** hydrogen bonding between the –OH and $–NO_2$ groups of the same molecule. B = ***p*-nitrophenol** (4-nitrophenol), with **intermolecular** hydrogen bonding between different molecules. [1]<br>(ii) ***o*-Nitrophenol** is steam volatile: the intramolecular hydrogen bond prevents association, so its molecules are held together only weakly and it is more volatile. In *p*-nitrophenol the intermolecular hydrogen bonding causes association of molecules, so it is less volatile. [1]<br>(iii) By steam distillation: *o*-nitrophenol distils over with steam, and *p*-nitrophenol is left in the flask. [1]<br>**(B)**<br>(i) $C_6H_5OH + NaOH \rightarrow C_6H_5ONa$; $C_6H_5ONa + CO_2 \rightarrow o\text{-}HOC_6H_4COONa \rightarrow (H^+)$ *o*-hydroxybenzoic acid (salicylic acid). [1]<br>(ii) $C_6H_5OH + CHCl_3 + 3NaOH \rightarrow$ (via the substituted benzal chloride) $\rightarrow o\text{-}HOC_6H_4CHO$ (salicylaldehyde) after acidification. [1]<br>(iii) The negative charge on the oxygen of the phenoxide ion is delocalised into the ring, increasing the electron density at the ortho and para positions much more than in phenol, so even a weak electrophile such as $CO_2$ can attack. [1] | 1 + 1 + 1 |
| **14** | **(A)**<br>(i) **X = cumene hydroperoxide**; **Y = phenol** ($C_6H_5OH$); **Z = acetone** (propanone, $CH_3COCH_3$), the by-product. [1]<br>(ii) W = **2,4,6-tribromophenol** (white precipitate): $C_6H_5OH + 3Br_2 \rightarrow C_6H_2Br_3OH + 3HBr$. [1]<br>(iii) V = **salicylic acid** (2-hydroxybenzoic acid), obtained by **Kolbe's reaction** (phenol + NaOH, then $CO_2$, then $H^+$). [1]<br>**(B)**<br>(i) $C_6H_5ONa + C_2H_5Br \rightarrow C_6H_5OC_2H_5 + NaBr$ (sodium phenoxide + bromoethane). [1]<br>(ii) **2-Methylpropene** is formed, because the alkoxide ion is a strong base as well as a nucleophile, and with a tertiary alkyl halide elimination predominates over substitution. [1]<br>(iii) Sodium *tert*-butoxide, $(CH_3)_3CONa$, with a primary halide, bromoethane: $(CH_3)_3CONa + C_2H_5Br \rightarrow (CH_3)_3COC_2H_5 + NaBr$. [1] | 1 + 1 + 1 |

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| **15** | **(A)**<br>(i) $C_6H_5OH$ (phenol) + $CH_3I$. [1]<br>(ii) $(CH_3)_3C–I + C_2H_5OH$: when one group is tertiary the halide formed is the tertiary one, via a stable carbocation ($S_N1$). [1]<br>(iii) $CH_3I + C_2H_5OH$: with primary alkyl groups the iodide ion attacks the lower (less substituted) alkyl group by $S_N2$. [1]<br>**(B)**<br>(i) A mixture of *o*- and *p*-bromophenol (monobromophenols): $C_6H_5OH + Br_2 \rightarrow$(CS$_2$, low temp.) *o*/*p*-$BrC_6H_4OH + HBr$. [1]<br>(ii) 2,4,6-Tribromophenol (white precipitate): $C_6H_5OH + 3Br_2 \rightarrow C_6H_2Br_3OH + 3HBr$. [1]<br>(iii) 2,4,6-Trinitrophenol (picric acid): $C_6H_5OH + 3HNO_3 \rightarrow$(conc.) $C_6H_2(NO_2)_3OH + 3H_2O$. [1] | 1 + 1 + 1 |

## SECTION D

Question No. 16 is a case-based/data-based question carrying 4 marks.

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| **16** | (i) Strongest acid: ***p*-nitrophenol** (lowest p$K_a$ = 7.1); weakest: **ethanol** (p$K_a$ = 15.9). Phenol is more acidic than ethanol; the difference in p$K_a$ is 15.9 − 10.0 = 5.9, i.e. phenol is nearly a million (about $10^6$) times more acidic. [1]<br>(ii) The electron withdrawing $–NO_2$ group delocalises the negative charge of the phenoxide ion more effectively when it is at the ortho or para position: the negative charge appears on the carbon bonded to $–NO_2$ in the resonance structures and is stabilised by the nitro group. At the meta position, no resonance structure puts the charge on the carbon carrying $–NO_2$, so the effect is weaker (p$K_a$ 8.3). [1]<br>(iii) **(A)** In phenol the –OH is attached to the $sp^2$ hybridised carbon of the ring, which is more electronegative and withdraws electron density from oxygen, making the O–H bond more polar and favouring ionisation. In addition the phenoxide ion is stabilised by delocalisation of the negative charge over the ring (five resonating structures), whereas in the alkoxide ion the charge is localised on oxygen and the alkyl group is electron releasing. [2]<br>**(B)** The methyl group is electron releasing (+I effect and hyperconjugation). It increases the electron density on the ring and the oxygen, which does not favour the formation (and stabilisation) of the cresoxide ion; therefore ionisation is less than in phenol (p$K_a$ 10.1–10.2 against 10.0). [2] | 1 + 1 + 2 |

## SECTION E

Question No. 17 is a long answer question carrying 5 marks.

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| **17** | **(A)**<br>(i) Step 1: formation of protonated alcohol: $CH_3CH_2–OH + H^+ \rightarrow CH_3CH_2–O^+H_2$. Step 2: formation of carbocation by loss of water: $CH_3CH_2–O^+H_2 \rightarrow CH_3CH_2^+ + H_2O$. Step 3: elimination of a proton to form ethene: $CH_3–CH_2^+ \rightarrow CH_2=CH_2 + H^+$. [3: 1 each]<br>(ii) Step 2 (formation of the carbocation) is the slowest, rate determining step. [½]<br>(iii) The acid used in step 1 is regenerated in step 3; removing ethene as it forms drives the equilibrium to the right (Le Chatelier's principle). [½]<br>(iv) At **413 K** with conc. $H_2SO_4$ ethoxyethane is the main product. Bimolecular dehydration of a mixture of ethanol and methanol would give a mixture of three ethers (diethyl ether, dimethyl ether and ethyl methyl ether), so it is not suitable for an unsymmetrical ether. [1]<br>**(B)** (1 mark each)<br>(i) $CH_3CH_2OH \rightarrow$(PCC, or $CrO_3$ in anhydrous medium) $CH_3CHO$ [1]<br>(ii) $CH_3CH_2OH \rightarrow$(acidified $KMnO_4$, a strong oxidising agent) $CH_3COOH$ [1]<br>(iii) $CH_3CH(OH)CH_3 \rightarrow$($CrO_3$) $CH_3COCH_3$ [1]<br>(iv) $CH_3CH_2CH_2OH \rightarrow$(Cu, 573 K, dehydrogenation) $CH_3CH_2CHO + H_2$ [1]<br>(v) $(CH_3)_3C–OH \rightarrow$(Cu, 573 K) $(CH_3)_2C=CH_2 + H_2O$ (a tertiary alcohol undergoes dehydration and is not oxidised under mild conditions). [1] | 5 |

### Topic coverage of the paper

| Topic (NCERT section) | Questions |
|---|---|
| Classification and nomenclature (7.1, 7.2) | Q1, Q2 (table) |
| Preparation of alcohols: hydration, hydroboration, reduction, Grignard (7.4.1) | Q4, Q10 |
| Preparation of phenols: cumene, diazonium salts, etc. (7.4.2) | Q14 (figure) |
| Physical properties: boiling point, solubility, hydrogen bonding (7.4.3, 7.6.2) | Q3 (figure), Q9 (B), Q13 (figure) |
| Acidity of alcohols and phenols (7.4.4) | Q5, Q8, Q16 (table) |
| Reactions of alcohols: Lucas test, dehydration, oxidation (7.4.4) | Q9 (table), Q12 (table), Q17 |
| Reactions of phenols: nitration, halogenation, Kolbe, Reimer–Tiemann (7.4.4) | Q6, Q12 (B), Q13, Q14, Q15 (B) |
| Commercially important alcohols (7.5) | Q11 |
| Ethers: Williamson synthesis, cleavage with HI (7.6) | Q7, Q14 (B), Q15 (A), Q17 (A) |

Figure/table-based questions (7): Q2, Q3, Q9, Q12, Q13, Q14 and Q16.