

SH2 H2 Preliminary Exam Paper 1 Worked Solutions

1	D	11	D	21	B	31	B
2	C	12	D	22	C	32	D
3	B	13	C	23	A	33	B
4	A	14	C	24	B	34	B
5	D	15	D	25	B	35	D
6	C	16	D	26	D	36	B
7	A	17	B	27	D	37	A
8	C	18	A	28	A	38	C
9	B	19	A	29	B	39	A
10	C	20	B	30	C	40	C

Section A

Amt of $\text{H}_2 = 3/2 \text{ mol}$

Amt of $\text{Br}_2 = 160/159.8 = 1 \text{ mol}$ (limiting agent)

Hence, amt of HBr formed = 2 mol

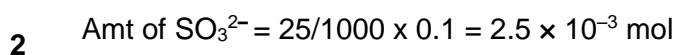
No of molecules present at the end of reaction

$$= (2+1/2) \times 6.0 \times 10^{23}$$

$$= 1.5 \times 10^{22}$$

$$= 15.1 \times 10^{23}$$

Ans: **D**



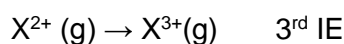
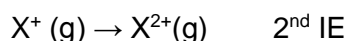
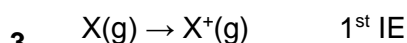
$$\text{Amt of } e^- = 2 \times 2.5 \times 10^{-3} = 5.0 \times 10^{-3} \text{ mol}$$

$$\text{Amt of metallic salt} = 50/1000 \times 0.1 = 5.0 \times 10^{-3} \text{ mol}$$

Hence mole ratio of metallic salt : e^- is 1:1

Since original oxidation number of the metal in the salt is +3, after gaining 1 e^- , the new oxidation number will be +2.

Ans: **C**



3^{rd} ionization energy peaks at Grp II elements, where the removal of the electron involves an electron in the inner quantum shell, hence requiring a lot more energy.

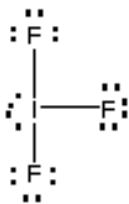
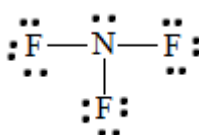
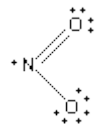
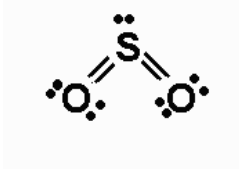
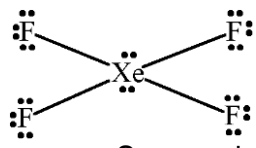
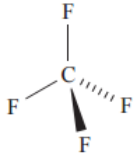
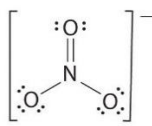
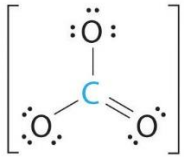
Hence element **M** is in Grp II. Element **R** is in Grp VII. So the compound **MR₂** is formed between elements **M** and **R**.

Element **O** is in Grp IV and element **P** is in Grp V. The 3^{rd} IE of **O** involves removing the 2s electron whereas for **P**, it involves removing the 2p electron. Since electron in 2p subshell has less nuclear attraction than electron in 2s subshell, less energy is required to remove it.

Ans: **B**

4	A	C ₆₀ C ₂ H ₅ COONH ₄ SiO ₂	simple covalent structure giant ionic structure giant covalent structure
	B	CO ₂ Na ₂ O SO ₂	simple covalent structure giant ionic structure simple covalent structure
	C	Al ₂ O ₃ PbO SiO ₂	giant ionic structure giant ionic structure giant covalent structure
	D	AlCl ₃ P ₄ O ₆ KHF ₂	simple covalent structure simple covalent structure giant ionic structure

Ans: **A**

5	A	IF ₃		T-shape
		NF ₃		Trigonal pyramidal
	B	NO ₂		bent
		SO ₂		bent
	C	XeF ₄		Square planar
		CF ₄		Tetrahedral
	D	NO ₃ ⁻		Trigonal planar
		CO ₃ ²⁻		Trigonal planar

Note: Though NO₂ and SO₂ have the same shape, they have different bond angles due to different repulsion between lone pair-bond pair and lone electron-bond pair.

Ans: **D**

6

The dominant intermolecular forces of attraction between iodine is temporary dipole induced dipole interactions, while that between water is hydrogen bonding. Since iodine exists as solid while water exists as liquid at rtp, it implies that the temporary dipole induced dipole interactions between iodine are stronger than the H-bonds between water, requiring more energy to break, and energy at r.t.p is insufficient to break them, hence they exist as solid.

Ans: **C**

7 At constant pressure,

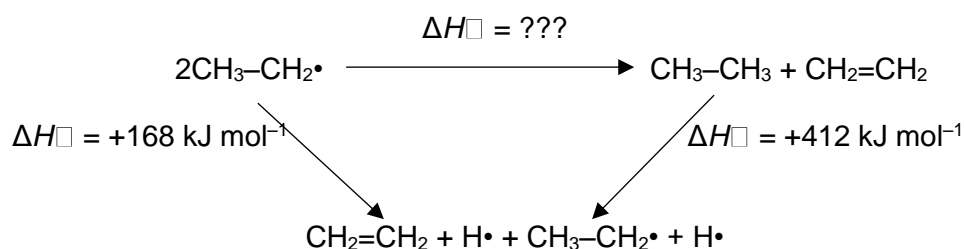
$$\frac{V_1}{T_1} = \frac{V_2}{T_2}$$

$$\frac{1.0}{293} = \frac{V_2}{313}$$

$$V_2 = 1.07 \text{ dm}^3 \text{ (approximately } 1.1 \text{ dm}^3\text{)}$$

Ans: A

8



$$\text{By Hess's law, } \Delta H = +168 - 412 = -244 \text{ kJ mol}^{-1}$$

Ans: C

9

Option A: $\text{Mg(g)} \rightarrow \text{Mg}^{2+}(\text{g})$ 1st IE + 2nd IE

Option B: **Standard enthalpy change of formation of water** refers to the energy released or absorbed when 1 mole of water is formed from its constituent elements in their standard states under standard conditions.

Standard enthalpy change of neutralisation is the energy released when one mole of water is formed from H^+ and OH^- under standard conditions.

Therefore, step B represents $2 \times \Delta H_{\text{neutralisation}}$

$$\begin{aligned} \text{Option C: By Hess's law, } \Delta H \text{ for step C} &= +146 + 736 + 1450 + 166 - 1926 - 796 \\ &= -274 \text{ kJ mol}^{-1} \end{aligned}$$

Option D: **Standard enthalpy change of hydration** is the energy released when one mole of gaseous ions is hydrated into aqueous ions under standard conditions.

Ans: B

- 10 Equilibrium constant, K_c , is temperature dependent, i.e. it changes only if temperature changes.

Option **A** is **not** true as the total pressure of the reaction mixture remains constant since the total number of gaseous particles remained unchanged.

Option **B** is **not** true as the position of the equilibrium has time to change due to slow cooling of reaction mixture. The eqm constant determined is likely one at well below 300 °C.

Option **C** is true as the position of the equilibrium has no or little time to change due to rapid cooling of reaction mixture. The eqm constant determined is likely to be one at 300 °C.

Option **D** is **not** true as the method gives only the initial amount of iodine used.

Ans: **C**

- 11 Option **A** is **not** true as decreasing the pressure favours forward reaction to produce more **F**; less **E** would remain.

Option **B** is **not** true as adding a catalyst would not affect the position of the equilibrium, but allows the equilibrium to be established faster.

Option **C** is **not** true as the equilibrium constant decreases with increasing temperature, which implies backward reaction is favoured as temperature increases. Thus backward reaction must be endothermic.

Option **D** is true as it can be deduced that $\Delta H < 0$ and $\Delta S > 0$ (due to an increase in no of gaseous particles in the reaction); thus $\Delta G = \Delta H - T\Delta S < 0$ at all temperatures; reaction should be feasible at all temperatures.

Ans: **D**

- 12
$$t_{1/2} = \frac{\ln 2}{k} = \frac{\ln 2}{0.26} = 2.66 \text{ h}$$

When 75% of the paracetamol consumed is removed, it means 25% ($= \frac{1}{4}$) of the paracetamol consumed remains and 2 $t_{1/2}$ must have lapsed.

$$\therefore t = 2t_{1/2} = 5.3 \text{ h}$$

Ans: **D**

- 13 Since total vol of reaction was kept constant in all 4 expts, concentration of each reactant \propto its volume used

Comparing data from expt 1 & 2, when vol of **B** is halved (while keeping vol of **A** and **Y** constant), rate is also halved \Rightarrow order of reaction wrt **B** is 1

Comparing data from expt 1 & 3, when vol of **Y** is halved (while keeping vol of **A** and **B** constant), rate is also halved \Rightarrow order of reaction wrt **Y** is 1

Comparing data from expt 1 & 4, when vol of **A** is halved (while keeping vol of **B** and **Y** constant), rate remains unchanged \Rightarrow order of reaction wrt **A** is 0

Ans: **C**

- 14 Using E° values from *Data Booklet*, only $\text{Fe}^{3+}(\text{aq})$ can oxidise $\text{Na}_4\text{Fe}(\text{CN})_6$ to $\text{Na}_3\text{Fe}(\text{CN})_6$ as $E^\circ_{\text{cell}} = +0.77 - (+0.36) = +0.41 \text{ V} > 0$ and reaction is feasible.

Option **A** is **not** true as $\text{Cl}^-(\text{aq})$ is a reducing agent.

Option **B** is **not** true as $E^\circ_{\text{cell}} = +0.15 - (+0.36) < 0$ if $\text{Cu}^{2+} \rightarrow \text{Cu}^+$ or $E^\circ_{\text{cell}} = +0.34 - (+0.36) < 0$ if $\text{Cu}^{2+} \rightarrow \text{Cu}$

Option **D** is **not** true as $E^\circ_{\text{cell}} = -2.38 - (+0.36) < 0$

Ans: **C**

- 15 Option **A** is **not** true as dissociation of water involves breaking of O–H bonds and must be endothermic.

Option **B** is **not** true as dissociation of water always results in the same amount of $\text{H}^+(\text{aq})$ and $\text{OH}^-(\text{aq})$ formed; $\text{pH} = \text{pOH}$

Option **C** is **not** true as $[\text{H}^+(\text{aq})] = [\text{OH}^-(\text{aq})]$ is always true, i.e. water is neutral, at all temperatures.

Option **D** is true as values of $K_a = \frac{K_w}{55.5} = 1.8 \times 10^{-16}$, $K_w = 10^{-14}$ and $[\text{H}^+] = 10^{-7}$

Ans: **D**

- 16 Option **A** is true and hence is **not** the answer. At the equivalence point of a strong acid – weak base titration, the solution usually has $\text{pH} < 7$.

Option **B** is true and hence is **not** the answer. pH of 0.10 mol dm^{-3} acid with $K_a = 10^{-5} \text{ mol dm}^{-3}$ is 3 and the indicator is yellow in colour.

Option **C** is true and hence is **not** the answer. pH of a solution with $[\text{CH}_3\text{CO}_2\text{H}] = [\text{CH}_3\text{CO}_2\text{K}] = 4.76$ ($\text{p}K_a$) (between 3.8 - 5.5); solution has $[\text{In}] \approx [\text{HIn}^+]$ and indicator will be green in the solution.

Option **D** is **not** true and hence is the answer. The end-point of an acid-base titration occurs when $[\text{In}] \approx [\text{HIn}^+]$ and colour of the solution should be green (due to about equal amount of both yellow and blue species). Colour change at end-point should be from yellow to **green**, not blue.

Ans: **D**

- 17 NaCl dissolves in water to form a neutral solution of $\text{pH} = 7$.

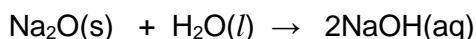


Na^+ does not hydrolyse in water because of low charge density. Cl^- is a weak conjugate base of the strong acid HCl ; hence does not hydrolyse in water.

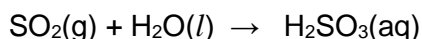
SiCl_4 hydrolyses in water to give an acidic solution of $\text{pH} = 2$



Na_2O dissolves in water to form a strongly alkaline solution of NaOH ($\text{pH} = 13$ or 14).



SO_2 dissolves in water to form an acidic solution of $\text{H}_2\text{SO}_3(\text{aq})$



Hence mixing of

- | | |
|--|--|
| A NaCl and $\text{Na}_2\text{O} \rightarrow \text{pH} > 7$ | C NaCl and $\text{SO}_2 \rightarrow \text{pH} < 7$ |
| B Na_2O and $\text{SiCl}_4 \rightarrow \text{pH} = 7$ | D SiCl_4 and $\text{SO}_2 \rightarrow \text{pH} < 7$ |

Ans: **B**

- 18 Si is insoluble in HCl , while MgO reacts with HCl to give MgCl_2 and water (acid-base reaction). Hence Si remains as residue while the filtrate contains $\text{MgCl}_2(\text{aq})$.

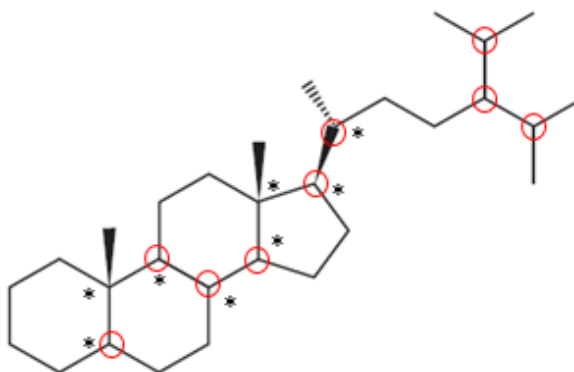
MgO and Si do not evaporate on heating due to high melting/boiling point.

Ans: **A**

- 19 Inter-electronic repulsion between the lone pairs on F atoms in a F_2 molecule causes the F-F bond to be longer and weaker than expected.

Ans: **A**

- 20 Tertiary carbons circled in red.
Chiral carbons with *



Ans: **B**

- 21 Reaction pathway diagram shows S_N1 mechanism, i.e. 2-step reaction.

S_N1 is favoured when the reactant can form a stable carbocation intermediate, hence usually involves tertiary halogenoalkanes (i.e. option I) and not primary halogenoalkanes (options II and IV). Electron donating alkyl groups can help to ease the positive charge on the carbocation.

For option III, $C_6H_5CH_2Cl$ can form a stable carbocation $C_6H_5\overset{+}{CH}_2$, the carbocation is stabilised by resonance as the electron deficient carbon is adjacent to a benzene ring.

Ans: **B**

- 22 Due to the lack of dipole moments in alkane molecules, there is a lack of electron-rich and electron deficient centres to attract nucleophiles and electrophiles for reaction.

Ans: **C**

- 23 Step 1: oxidation of primary alcohol to aldehyde

Step 2: nucleophilic addition of aldehyde

Step 3: oxidation (loss of hydrogen)

Ans: **A**

- 24 Option **A**: oxidation of methyl side-chain on $C_6H_5CH_3$ gives C_6H_5COOH

Option **B**: electrophilic substitution of $C_6H_5CH_3$ gives 2-bromomethylbenzene or 4-bromomethylbenzene as the main products, 3-bromomethylbenzene is a minor product. Alkyl chain on benzene is 2,4-directing.

Option **C**: Free radical substitution of methyl side-chain on $C_6H_5CH_3$ gives $C_6H_5CH_2Br$.

Option **D**: electrophilic substitution of $C_6H_5CH_3$ gives in 2-nitromethylbenzene or 4-nitromethylbenzene as the main products.

Ans: **B**

- 25 In Step I, phenol can only be deprotonated by either (i) Na or (ii) NaOH but not Na_2CO_3 .

Step II is a nucleophilic attack on an electron deficient carbon (C bonded to Cl instead of C bonded to OH since the C-Cl bond is weaker). Check that the number of carbon atoms are correct.

Ans: **B**

- 26 A zwitterion is a dipolar species with no net charges (where $-CO_2H$ can be deprotonated by the $-NH_2$ group). So options **A**, **B** and **D** have possibility of forming zwitterions. **X** must also contain a chiral centre (carbon bonded to four different groups) since it is optically active.

Ans: **D**

27

A	<p> $\text{H}-\text{C}(\text{Br})_2-\text{C}(\text{Br})_2-\text{H} \xrightarrow[\text{heat}]{\text{aqueous NaOH}} \text{H}-\text{C}(\text{OH})_2-\text{C}(\text{OH})_2-\text{H} \xrightarrow[\text{heat}]{\text{acidified KMnO}_4} \text{O}=\text{C}(\text{OH})-\text{C}(\text{OH})=\text{O}$ </p> <p>(COOH)₂ will get oxidised to CO₂ and H₂O when KMnO₄ is used as oxidising agent.</p>
B	<p> $\text{C}_6\text{H}_5\text{CH}_3 \xrightarrow[\text{FeBr}_3]{\text{aqueous Br}_2} \text{C}_6\text{H}_4(\text{Br})\text{CH}_3 \xrightarrow[\text{heat}]{\text{acidified KMnO}_4} \text{C}_6\text{H}_4(\text{Br})\text{COOH}$ </p> <p>The 1st step should be carried out under anhydrous conditions as water will destroy the halogen carrier, FeBr₃.</p>
C	<p> $\text{C}_6\text{H}_5\text{OH} \xrightarrow{\text{aq. Br}_2} \text{C}_6\text{H}_2(\text{Br})_3\text{OH} \xrightarrow[\text{conc. H}_2\text{SO}_4, \text{ heat}]{\text{CH}_3\text{CO}_2\text{H}} \text{C}_6\text{H}_2(\text{Br})_3\text{OCOCH}_3$ </p> <p>The 2nd step can only be carried out with acid chloride (in the presence of aq NaOH) as phenols are too unreactive to react with carboxylic acid in a condensation reaction.</p>
D	<p> $\text{C}_6\text{H}_{11}\text{C}(=\text{O})\text{CH}_2\text{I} \xrightarrow{\text{NaBH}_4} \text{C}_6\text{H}_{11}\text{CH}(\text{OH})\text{CH}_2\text{I} \xrightarrow[\text{NaOH, heat}]{\text{I}_2} \text{C}_6\text{H}_{11}\text{COO}^-$ </p> <p>The 1st step is a reduction of ketone to a secondary alcohol. The 2nd step is an iodoform (oxidation) reaction due to presence of -CH(OH)CH₂I.</p> <p>Note: -CH₃ can be replaced by -CH₂I or -CHI₂ in the structure. Both steps are feasible.</p>

Ans: D

28

Positive test with [Ag(NH₃)₂]⁺ (Tollen's reagent) => Aldehyde is present.
 Positive test with PCl₅ => RCO₂H or ROH is present (not phenol)
 Negative test with alkaline Cu(II) tartrate (Fehling's solution) => aliphatic aldehyde is absent.

Ans: A

29	A	CCl ₃ CH ₂ OH, CHCl ₂ CH ₂ OH, CH ₃ COOH CH ₃ COOH is the most acidic as it is a carboxylic acid, the first two molecules are alcohols.
	B	CH ₃ CHClCOOH, CH ₃ CH ₂ COOH, C ₆ H ₅ OH CH ₃ CHClCOOH and CH ₃ CH ₂ COOH are more acidic than C ₆ H ₅ OH as they are carboxylic acids while C ₆ H ₅ OH is phenol. CH ₃ CHClCOOH is most acidic as the electron withdrawing Cl disperses the negative charge on the conjugate base and hence stabilises it.
	C	C ₆ H ₅ OH, CH ₃ CHClCOOH, CH ₃ CHF ₂ COOH Phenol is less acidic than carboxylic acids.
	D	CH ₂ ClCH ₂ COOH, CH ₃ CHClCOOH, CH ₃ CH ₂ COOH CH ₃ CHClCOOH is more acidic than CH ₂ ClCH ₂ COOH due to the closer proximity of the electron withdrawing Cl to the -COOH, which can better help to disperse the charge on the conjugate base.

Ans: **B**

- 30 2, 4-dinitrophenylhydrazine reacts with carbonyl compounds via condensation, forming a new C=N bond. Phenylhydrazine reacts in similar way with the ketone in compound **O**. The ester functional group does not react with phenylhydrazine.

Ans: **C**

Section B

31	1	N ⁻ C ⁺	1s ² 2s ² 2p ⁴ 1s ² 2s ² 2p ¹	2 unpaired e ⁻ 1 unpaired e ⁻
	2	Mn ²⁺ Co ²⁺	[Ar] 3d ⁵ [Ar] 3d ⁷	5 unpaired e ⁻ 3 unpaired e ⁻
	3	Mn ⁴⁺ Co	[Ar] 3d ³ [Ar] 3d ⁷ 4s ²	3 unpaired e ⁻ 3 unpaired e ⁻

Ans: **B**

- 32 Option **2**: Hydrogen should exist as molecular H₂(g) instead of H(g) under standard conditions.
Option **3**: H₂O should exist as liquid instead of gas under standard conditions.

Ans: **D**

- 33 Option **1** is true as RCO₂H has a smaller K_a means it is a weaker acid and dissociates in aq solution to give a lower [H⁺(aq)] and thus has a higher pH.

Option **2** is true as K_a × K_b = K_w = 10⁻¹⁴ mol² dm⁻⁶. An acid with a larger K_a would give a conjugate base with a lower K_b value and vice versa.

Option **3** is **not** true as R₁CO₂H has a larger K_a means it is the stronger acid.

Ans: **B**

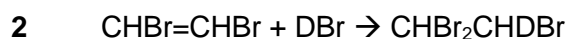
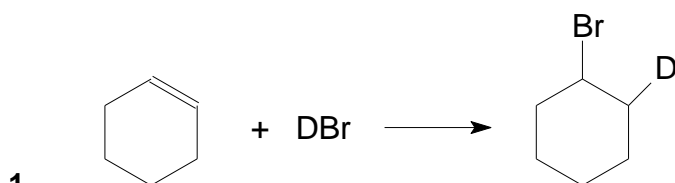
- 34 Option 1 is true as each NH_3 donates H^+ (act as Bronsted acid) to form NH_2^- .
 Option 2 is true as Na is oxidised to Na^+ in NaNH_2 .
 Option 3 is **not** true as NH_3 acts a nucleophile in the reaction.

Ans: **B**

- 35 Option 1 is true as BaSO_4 will remain insoluble and not dissociate to give poisonous Ba^{2+} ions.
 Option 2 is **not** true as BaCO_3 will react with HCl(aq) in the stomach to release poisonous Ba^{2+} ions.
 Option 3 is **not** true as Ba(OH)_2 will react with HCl(aq) in the stomach to release poisonous Ba^{2+} ions.

Ans: **D**

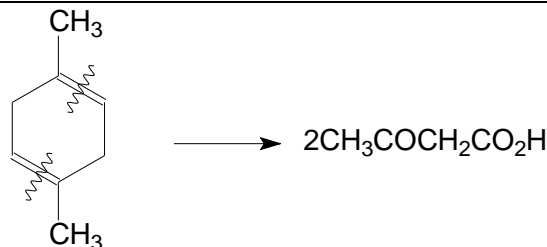
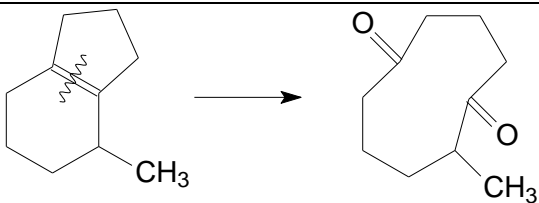
36



3 cannot be formed in a single step

Ans: **B**

37

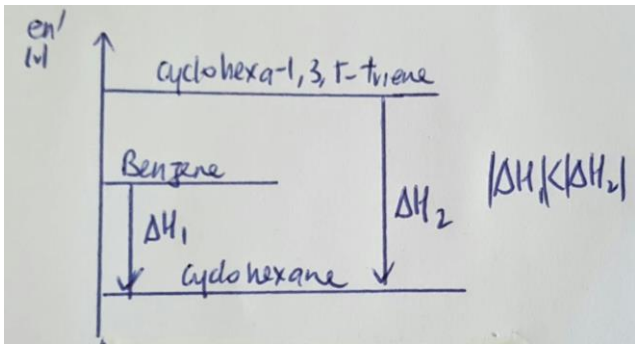
1	
2	
3	$\text{CH}_3\text{--CH}_2\text{--CH}_2\text{--CH=CH}_2 \rightarrow \text{CH}_3\text{CH}_2\text{CH}_2\text{COOH} + \text{CO}_2 + \text{H}_2\text{O}$

Ans: **A**

- 38 $\text{CH}_3\text{CH}_2\text{OCOCH}_2\text{CH}_3 + \text{H}_2^{18}\text{O} \rightarrow \text{CH}_3\text{CH}_2\text{OH} + \text{CH}_3\text{CH}_2\text{CO}^{18}\text{OH}$ as the H of H_2^{18}O adds to the alcohol and the ^{18}OH of H_2^{18}O adds to the carboxylic acid in hydrolysis (H–OH bond in water breaks).

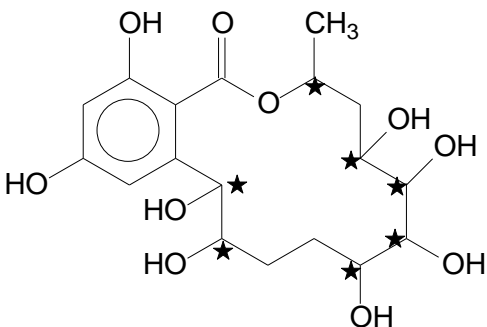
Ans: **C**

39

1	<p>Benzene does not undergo addition reactions.</p> <p>True. Addition will result in a loss of aromatic stability of benzene (loss of "alternate single and double bond")</p>
2	<p>The length of the C-C bonds in benzene are intermediate between C-C bond in an alkane and C=C bond in an alkene.</p> <p>True. The bond order of all C-C bonds in benzene are 1.5 due to resonance which arises from the continuous overlap of unhybridised p-orbitals.</p>
3	<p>The hydrogenation of benzene is less exothermic than that predicted for cyclohexa-1,3,5-triene.</p> <p>True. Benzene is more stable than cyclohexa-1,3,5-triene due to resonance. Thus, it exists at a lower energy level (see below). Hydrogenation of benzene gives cyclohexane.</p> 

Ans: A

40

1	<p>It reacts with hot, acidified $K_2Cr_2O_7$ to give a diketone.</p> <p>False. Hot acid will hydrolyse the ester to give a secondary alcohol which will then be oxidised to give a ketone. The other two secondary alcohols will also be oxidised to give 2 ketones. So the product will be a triketone.</p>
2	<p>One mole of Aigialomycin reacts with Na metal to produce 2 moles of hydrogen gas.</p> <p>True. One mol of hydroxyl group react with Na to produce 0.5 mole of gas. Since there is 4 hydroxy groups per mol of Aigialomycin, 2 moles of hydrogen gas are produced.</p>
3	<p>It reacts with cold, dilute acidified $KMnO_4$ to give a product that has 7 chiral centres.</p> <p>True. Alkene undergo mild oxidation to give diol. Product is shown below.</p> 

Ans: C

