

Chemistry Solutions (Organic)

Section A: Multiple Choice

1. **Answer:** -enoic acid

Working: Highest priority group is -COOH (carboxylic acid)
Longest carbon chain contains double bonds
→ alkene + carboxylic acid → -enoic acid

2. **Answer:** X = 83, Y = 68

Working: Fractions are only collected when they are gaseous at the top of the column so they can flow through the condenser
→ must be 68 °C at the top → Y = 68
Temperature in flask cannot be 98 °C otherwise a mixture would be obtained since both gases → X = 83

3. **Answer:** Pressure controlled at slightly above atmospheric pressure.

Working: The others are essential conditions.

4. **Answer:** 2-hydroxy-2-methyl-3-oxopentanedioic acid

Working: All primary/aldehyde and secondary -OH groups are oxidised to carboxylic acid or ketone groups. Tertiary alcohol not affected
→ 2-hydroxy-2-methyl-3-oxopentanedioic acid

5. **Answer:** 1 and 3 only

Working: 1 produces butan-1-ol (or butan-1-hydrogensulfate) (chiral)
2 produces 3-methylpentan-3-ol (not chiral)
3 produces 2,3-dimethylpentane (chiral)

6. **Answer:** Glycine

Working: The other three are on the data booklet, none of them are optically active so by process of elimination glycine is the answer

7. **Answer:** 1 only

Working: 1 is a secondary amine group (strongest)
2 is within the conjugated diene system so is weakened by delocalisation (weakest)
3 is a primary amine group (weaker than secondary)

8. **Answer:** A

Working: Most exothermic enthalpy of hydrogenation
→ least stable double bond → no resonance stabilisation
B, C and D all have double-single-double bonds → resonance

9. **Answer:** 3,3-diethylpentane

Working: Quick check: diethyl = $2 \times 2 = 4$ carbons, pentane = 5 carbons
→ total carbons = 9 → not an isomer of $C_{10}H_{22}$

10. **Answer:** A

Working: Z isomer has higher boiling point (more polar)
Carboxylic acid has higher boiling point (more hydrogen bonding/dimerisation)

11. **Answer:** 6

Working: For alkane chains, should have $C_{17}H_{35}$
($2n + 2 - 1 = 2 \times 17 + 1$ since one bond to other carbon)
→ 12 hydrogen atoms missing
→ 6 hydrogen molecules (since H_2)

12. **Answer:** The same types of bonds are formed as were broken.

Working: Bonds broken: C-O (alcohol) and O-H (carboxylic acid)
Bonds formed: C-O (ester) and O-H (water)
Bonds broken = bonds formed → almost no net change in enthalpy
(small difference due to different molecular environments)

13. **Answer:** 1 and 2 only

Working: 1: Yes (hydroxide and ethanal both appear once in step 1)
2: Yes (carbanion acts as nucleophile)
3: No (water loses a proton so it acts as an acid)

14. **Answer:** X: nitrobenzene, Y: phenylamine, Z: 1-(3-aminophenyl)propan-1-one

Working: To get amine group: nitrate followed by reduction
→ X is nitrobenzene, Y is phenylamine
To get alcohol, must reduce from phenylketone
→ Friedel-Crafts acylation: Z is 1-(3-aminophenyl)propan-1-one

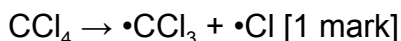
15. **Answer:** 1 and 3 only

Working: 1: Yes (acid anhydride + amine: uses nucleophilic addition followed by elimination)
2: No (nitrogen atom formed in the wrong place)
3: Yes (the ring opens up to form a straight chained product with carboxylic acid at one end and alcohol towards the other end)

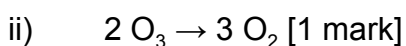
Section B: Standard Questions

16.

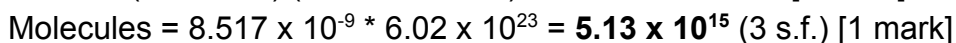
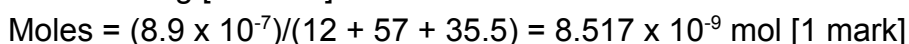
- a. Presence of **UV (ultraviolet) light / radiation** [1 mark]



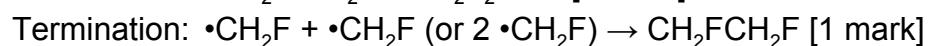
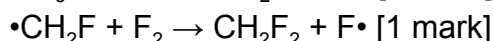
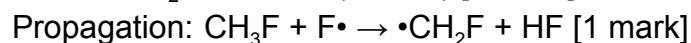
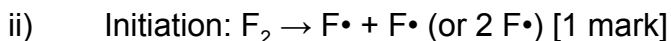
- b. i) $\text{Cl}\cdot + \text{O}_3 \rightarrow \text{ClO}\cdot + \text{O}_2$ [1 mark]
 $\text{ClO}\cdot + \text{O}_3 \rightarrow \text{Cl}\cdot + 2 \text{O}_2$ [1 mark]



- c. Mass of freon in $500 \text{ cm}^3 = 1.78 \times 10^{-4} \times (500/(100 \times 10^6)) = 8.9 \times 10^{-10} \text{ kg}$
 $= 8.9 \times 10^{-7} \text{ g}$ [2 marks]



- d. i) Free radical substitution



- e. $\text{NO}_2 + \text{O} \rightarrow \text{NO} + \text{O}_2$ [1 mark]

- f. CBrF_3 forms free atoms/radicals more readily [1 mark]

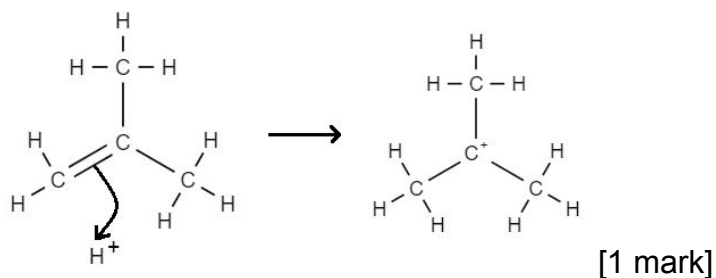
Because the C-Br bond is weaker/lower bond enthalpy than C-Cl [1 mark]

17.

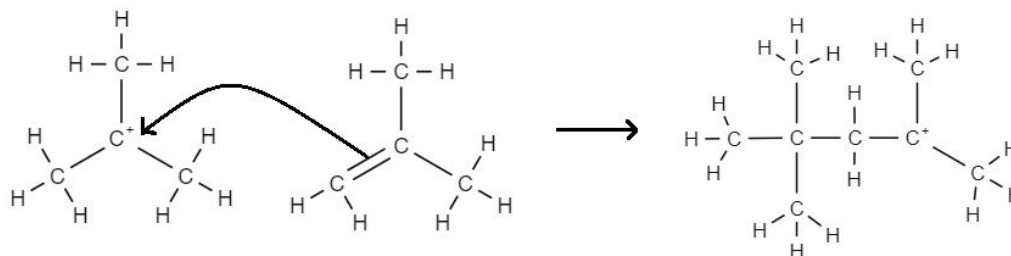
a. A process where two molecules of the **same species** [1 mark] form a **bond** [1 mark] (may be dative covalent or intermolecular)

b. i) Electrophilic addition [1 mark]

ii) Step 1: Occurs because the double bond is a region of **high electron density** [1 mark] so attracts/attacks the proton from the catalyst. Tertiary **carbocation** forms as it is **most stable**. [1 mark]

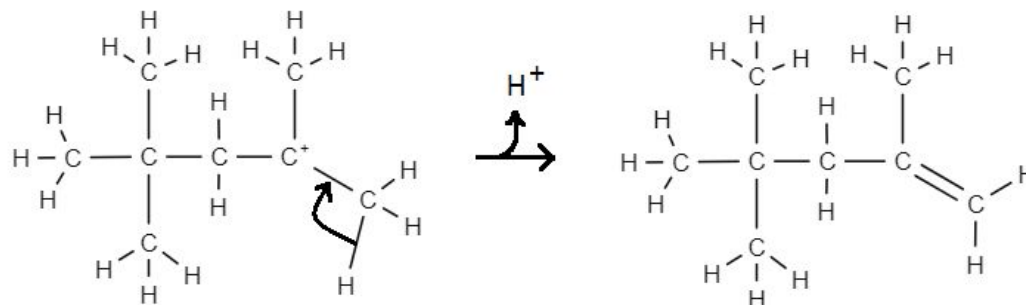


Step 2: Occurs for same reason as above.



[2 marks: no explanation needed]

Step 3: Occurs to **form the double bond**/resolve the carbocation [1 mark] and **regenerate/reform** the proton from the catalyst. [1 mark]

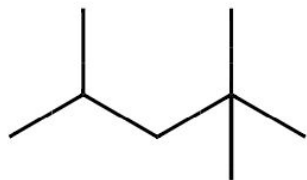


[1 mark]

iii) 2,4,4-trimethylpent-2-ene [1 mark]

- c. i) Position isomerism / regioisomerism [1 mark]
Not structural isomerism

- ii) Skeletal formula:



[1 mark]

Used as a (motor) fuel additive / component (to reduce engine knocking)
(common name: iso-octane) [1 mark]

18. Empirical formula:

$$66.63/12 : 11.18/1 : 22.19 / 16 = 5.55 : 11.2 : 1.39 = 4 : 8 : 1$$

→ empirical formula is C_4H_8O [1 mark]

M_r of empirical formula is $4 \times 12 + 8 + 16 = 72$

$144/72 = 2 \rightarrow$ molecular formula is $C_8H_{16}O_2$ [1 mark]

Infrared absorption at wavenumber $1700\text{ cm}^{-1} \rightarrow C=O$ bond \rightarrow ester [1 mark]

Total integration = 16 \rightarrow 1:1 ratio

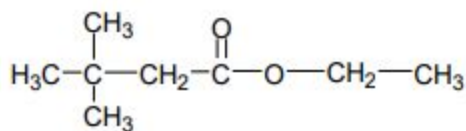
Singlet at 1 \rightarrow 3x CH_3 bonded to tertiary C [1 mark]

Triplet at 1.3 \rightarrow CH_3 bonded to CH_2 [1 mark]

Singlet at 2.2 \rightarrow CH_2 bonded to tertiary C [1 mark]

Quartet at 4 \rightarrow CH_2 bonded to oxygen [1 mark]

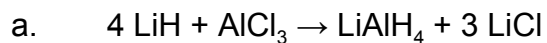
Combining consistently,



[1 mark]

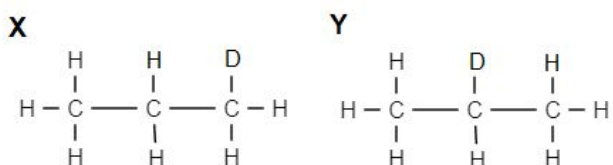
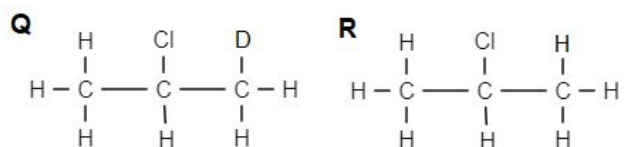
IUPAC name: **ethyl 3,3-dimethylbutanoate** [1 mark]

19.



[1 mark for identifying LiCl as the side product; 1 mark for correct balancing]

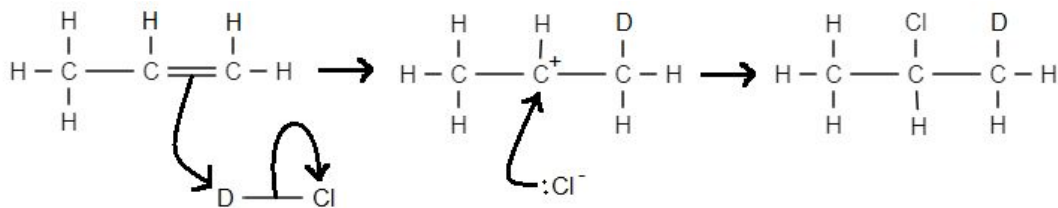
b. i) Structures are



(Accept skeletal/structural formulae. If skeletal then D must be shown)

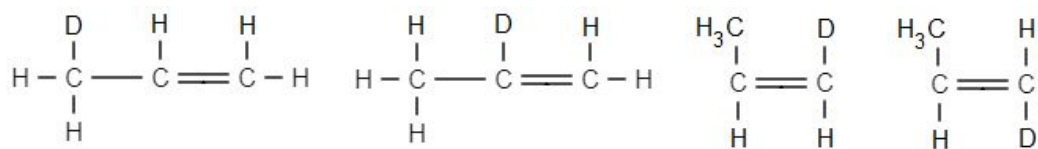
[1 mark each]

ii)



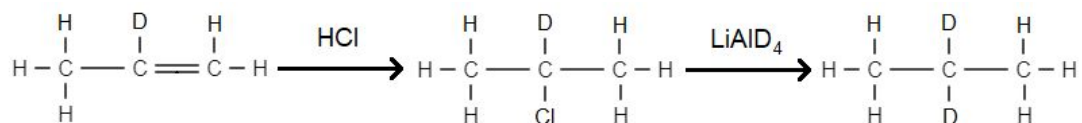
[1 mark for each correct arrow]

c. i)



[1 mark for each correct structure identified]

ii)



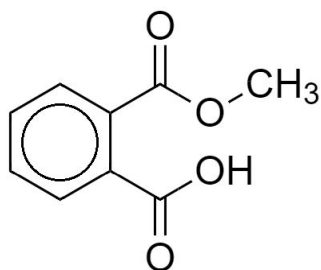
Z

2,2-dideuterated propane

[1 mark for correct structure of **Z**; 1 mark for identifying HCl as the first reagent; 1 mark for correct structure of intermediate; 1 mark for identifying LiAlD₄ as the second reagent; 1 mark for correct structure of final product]

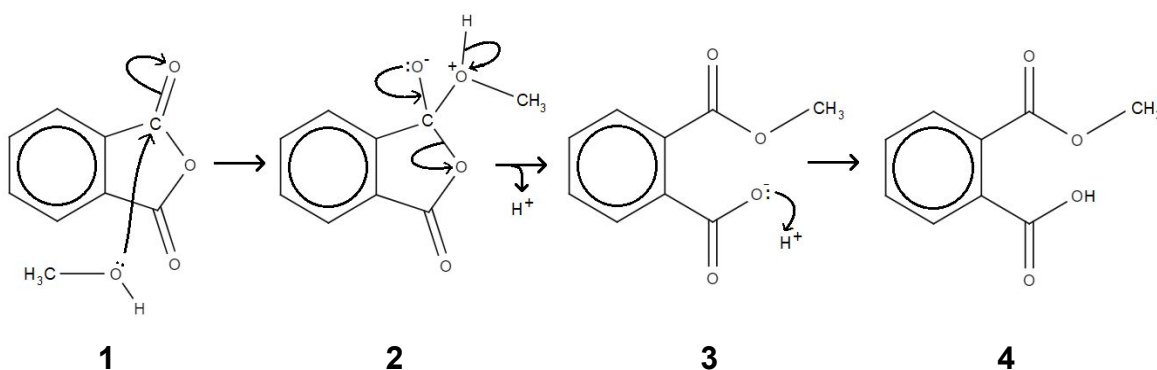
20.

- a. i) (CH_3 on ester group not explicitly required)



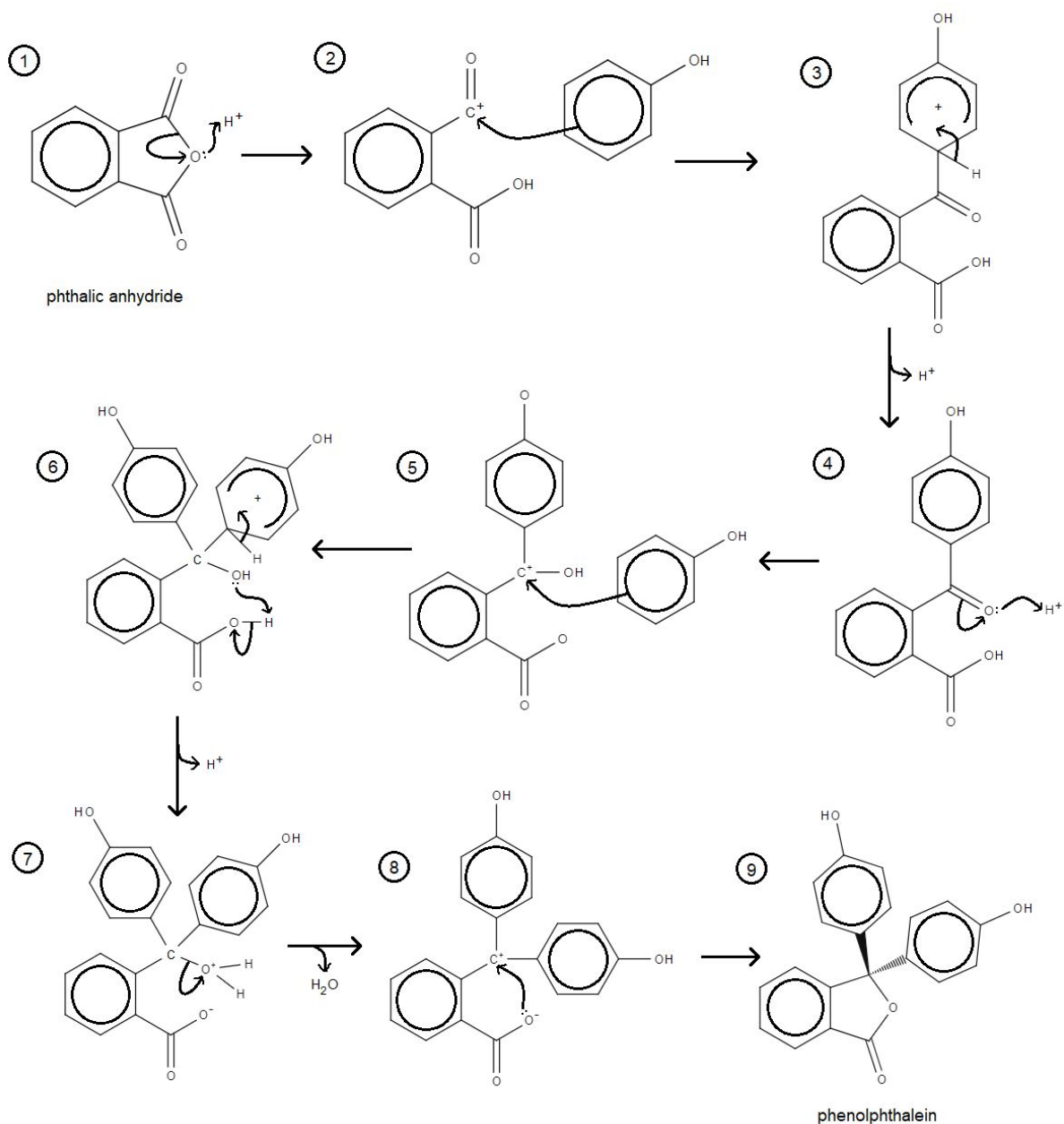
[1 mark for fully correct skeletal structure]

- ii) Nucleophilic addition-elimination [1 mark]



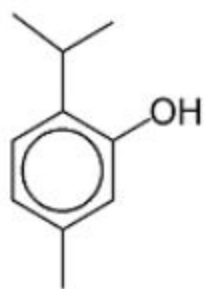
- 1: Lone pair on methanol attacks carbonyl (nucleophilic addition)
[1 mark]
2: Carbonyl reforms, opens up ring [1 mark], deprotonation [1 mark]
3: Protonation of carboxylate ion [1 mark]
4: Product formed

b.



- 1: Given (protonation by catalyst)
- 2: Electrophilic substitution (acylation) [1 mark]
- 3: Benzene ring reformed (deprotonation) [1 mark]
- 4: Carbonyl oxygen attacks catalyst (protonation), 3° C⁺ formed [2 marks]
- 5: Electrophilic substitution (acylation) [1 mark]
- 6: Benzene ring reformed (deprotonation) & proton transfer [2 marks]
- 7: Elimination of water (condensation), 3° C⁺ formed [1 mark]
- 8: Cyclic ester reformed (nucleophilic addition) [1 mark]
- 9: Product formed (stereochemistry not required)

c.



[1 mark]