

Victoria Junior College
2024 JC1 H2 Organic Chemistry Tutorial: Alkanes

Summary of Reactions

Complete the following table.

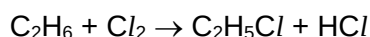
Starting compound	Reaction type	Reagents & Conditions	Products formed
$(\text{CH}_3)_2\text{C}=\text{CH}_2$	Reduction	OR	$(\text{CH}_3)_2\text{CHCH}_3$
CH_4			$\text{CCl}_4 + \text{HCl}$
$\begin{array}{c} \text{CH}_3-\text{CH}-\text{CH}_3 \\ \\ \text{CH}_3 \end{array}$		Limited Cl_2 , UV light (OR high temperature OR heat)	$\begin{array}{c} \text{CH}_3-\text{CCl}-\text{CH}_3 \\ \\ \text{CH}_3 \end{array}$ $\begin{array}{c} \text{CH}_3-\text{CH}-\text{CH}_2\text{Cl} \\ \\ \text{CH}_3 \end{array}$ + HCl

Introduction

- Write down the displayed formula and skeletal formula for each of the following.
 - 2,2-dimethylbutane
 - 3-ethyl-2,4-dimethylpentane
- Name the following compounds.
 - $\text{CH}_3(\text{CH}_2)_2\text{CH}(\text{CH}_3)\text{CH}(\text{CH}_3)_2$
 - $\text{CH}_3(\text{CH}_2)_2\text{CH}(\text{CH}_3)\text{CH}(\text{C}_2\text{H}_5)\text{CH}(\text{CH}_3)(\text{C}_2\text{H}_5)$

Reaction mechanism

- Chloroalkanes and bromoalkanes can be made by the reaction of the corresponding halogen with alkanes, for example:



- State the conditions needed for this reaction.
- Name and describe the mechanism of this reaction.
- Why is this reaction described as given in (b)?
- Suggest why it is **not** possible to make iodoalkanes by this method.

[N10/III/1(c) & (e)]

- 4 Propane undergoes free-radical substitution when mixed with chlorine and exposed to ultra-violet light.

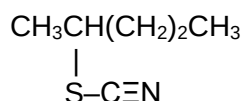
Which compounds are possible products from this reaction?

- 1 $\text{CH}_3\text{CH}_2\text{CH}_2\text{Cl}$
- 2 $\text{CH}_2\text{ClCH}_2\text{CH}_2\text{Cl}$
- 3 $\text{CH}_3\text{CH}_2\text{CH}_2\text{CH}_2\text{CH}_2\text{CH}_3$
- 4 $\text{CH}_3\text{CH}_2\text{CH}_2\text{CH}_2\text{CH}_3$

- A 1, 2 and 3 B 1, 3 and 4 C 1 and 2 only D 2 and 3 only
[N19/II/18]

- 5 Thiocyanogen, $(\text{SCN})_2$ is a symmetrical pseudohalogen which shows similar chemical reactivity to halogens.

When pentane is mixed with thiocyanogen in the presence of UV light, it reacts via the free radical mechanism and compound **A** was isolated.



Compound **A**

- (a) (i) Identify the radical formed in the initiation step for the formation of compound **A**.
- (ii) Write an equation to show how this radical is formed from $(\text{SCN})_2$. You are to draw the full structural formula of $(\text{SCN})_2$ and use arrows to indicate the movement of electrons so that it is clear which bonds are broken.
- (b) (i) Propose the 2 steps for the propagation stage of the reaction mechanism in the formation of compound **A** from pentane.
- (ii) Draw the two isomers of compound **A** which show different behaviours towards plane-polarised light.

[Modified 2014 VJC Promo P2S2]

Substitution at primary, secondary and tertiary carbon atoms

- 6 When an alkane **F**, with the formula C_6H_{14} , reacted with bromine under ultraviolet light, it produced **only two** isomeric monobromo compounds **G** and **H**, with the formula $\text{C}_6\text{H}_{13}\text{Br}$. Compound **H** was chiral.

- (a) Suggest the structures of **F**, **G** and **H**, explaining your reasoning.
- (b) Hence, state the expected ratio of the **two** isomeric monobromo compounds **G** and **H** formed based on the probability of substitution of the different classes of hydrogens by halogens.
- (c) From the above reactions, ratio of products obtained from probability consideration differs from experimental yield.
- (i) Suggest another factor that will affect the ratio of products obtained.
- (ii) Explain the factor which you have stated in (c)(i).

[Modified N08/III/2(g)]

Environmental Pollution and use of Catalytic Converters

- 7 A catalytic converter is part of the exhaust system of modern cars.

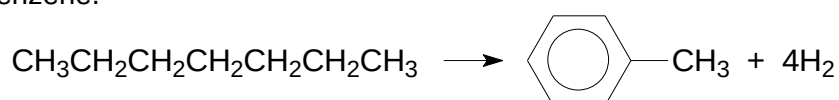
Which reactions occur in a catalytic converter?

- 1 $2C_xH_y + (4x + y)NO \rightarrow 2xCO_2 + yH_2O + (2x + y/2)N_2$
2 $2CO + 2NO \rightarrow 2CO_2 + N_2$
3 $CO_2 + NO \rightarrow CO + NO_2$
- A 1, 2 and 3.
B 1 and 2 only
C 2 and 3 only
D 1 only

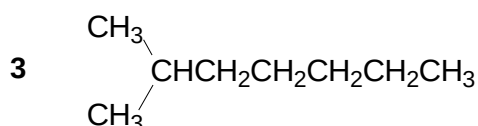
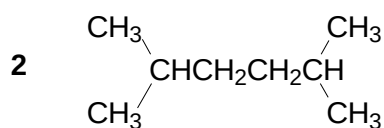
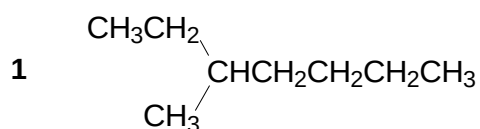
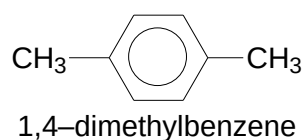
[N14/I/38]

Identification of reaction pattern

- 8 In an industrial process, heptane vapour is passed over a heated catalyst to make methylbenzene.



Under similar conditions, which of the C_8H_{18} isomers could give 1,4-dimethylbenzene?



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

[Modified N12/I/40]

1 What happens when one mole of ethane is mixed in the dark at room temperature with six moles of chlorine?

- 2** Two structural isomers of molecular formula C_6H_{14} are shown.

Q $\text{CH}_3\text{CH}_2\text{CH}(\text{CH}_3)\text{CH}_2\text{CH}_3$

How many possible **structural** isomers, each with formula $\text{C}_6\text{H}_{13}\text{Cl}$, could be produced by **P** and by **Q**?

	isomers formed by P	isomers formed by Q
A	5	3
B	5	4
C	6	3
D	6	4

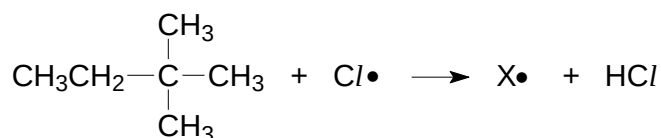
- B** $\text{Cl}_2 \rightarrow 2\text{Cl}^\bullet$

- D** $(\text{C}_6\text{H}_5)\text{CH}_3 \rightarrow (\text{C}_6\text{H}_5)\text{CH}_2^\bullet + \text{H}^\bullet$

- B** $\text{CH}_4 + \text{Cl}^+ \rightarrow \text{CH}_3\text{Cl} + \text{H}^+$

- D** $\text{CH}_4 + \text{Cl}^\bullet \rightarrow \text{CH}_3\text{Cl} + \text{H}^\bullet$

- 5** When heated with chlorine, the hydrocarbon 2,2-dimethylbutane undergoes free radical substitution. In a propagation step, the free radical $X\bullet$ is formed by the loss of one hydrogen atom.



How many different forms of $X_{\bullet}$ are theoretically possible?

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

- 6** The data below refers to straight chain alkanes.

No. of C atoms	Formula	B.p. / °C	Density of liquid alkane / g cm ⁻³
1	CH ₄	−161	0.42
3	C ₃ H ₈	−42	0.50
8	C ₈ H ₁₈	126	0.70
15	C ₁₅ H ₃₂	271	0.77
20	C ₂₀ H ₄₂	344	0.78

Explain the trend in boiling point and in density as shown by these data.

- 7 Describe the reagents and conditions used to produce chlorocyclopentane from cyclopentane and the mechanism of the reaction.

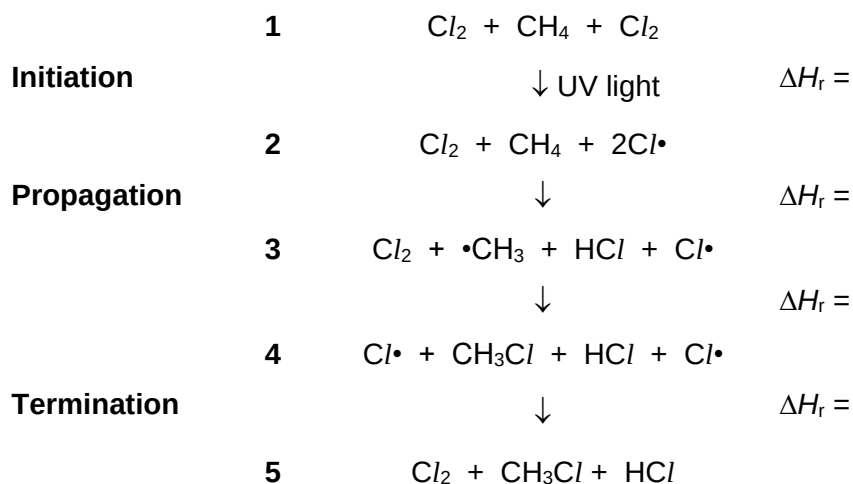
State the probability for chlorocyclopentane to undergo another substitution to form 1,2-dichlorocyclopentane.

8 Integrated question

- (a) Calculate the ΔH_r for each step as shown below with the given bond energy data.

Bond	Bond energy / kJ mol ⁻¹	Bond	Bond energy / kJ mol ⁻¹
H-H	436	Cl-Cl	244
H-Cl	431	C-Cl	340
H-C	410		

Free-Radical Substitution



- (b) Hence, draw the energy profile for the reaction between CH_4 and Cl_2 .
- (c) Using the energy profile diagram, explain why the use of UV light is only required for a short period of time.
- (d) Calculate the ΔH_r for the 2 equations and hence explain the feasibility of the two possible propagation steps.

$\text{CH}_4 + \text{Cl}\cdot \rightarrow \cdot\text{CH}_3 + \text{HCl}$	$\Delta H_r =$
$\text{CH}_4 + \text{Cl}\cdot \rightarrow \text{CH}_3\text{Cl} + \text{H}\cdot$	$\Delta H_r =$

Numerical Answers to supplementary questions:

- 8(a)** +244 kJ mol⁻¹, -21 kJ mol⁻¹, -96 kJ mol⁻¹, -244 kJ mol⁻¹
8(d) -21 kJ mol⁻¹, +70 kJ mol⁻¹