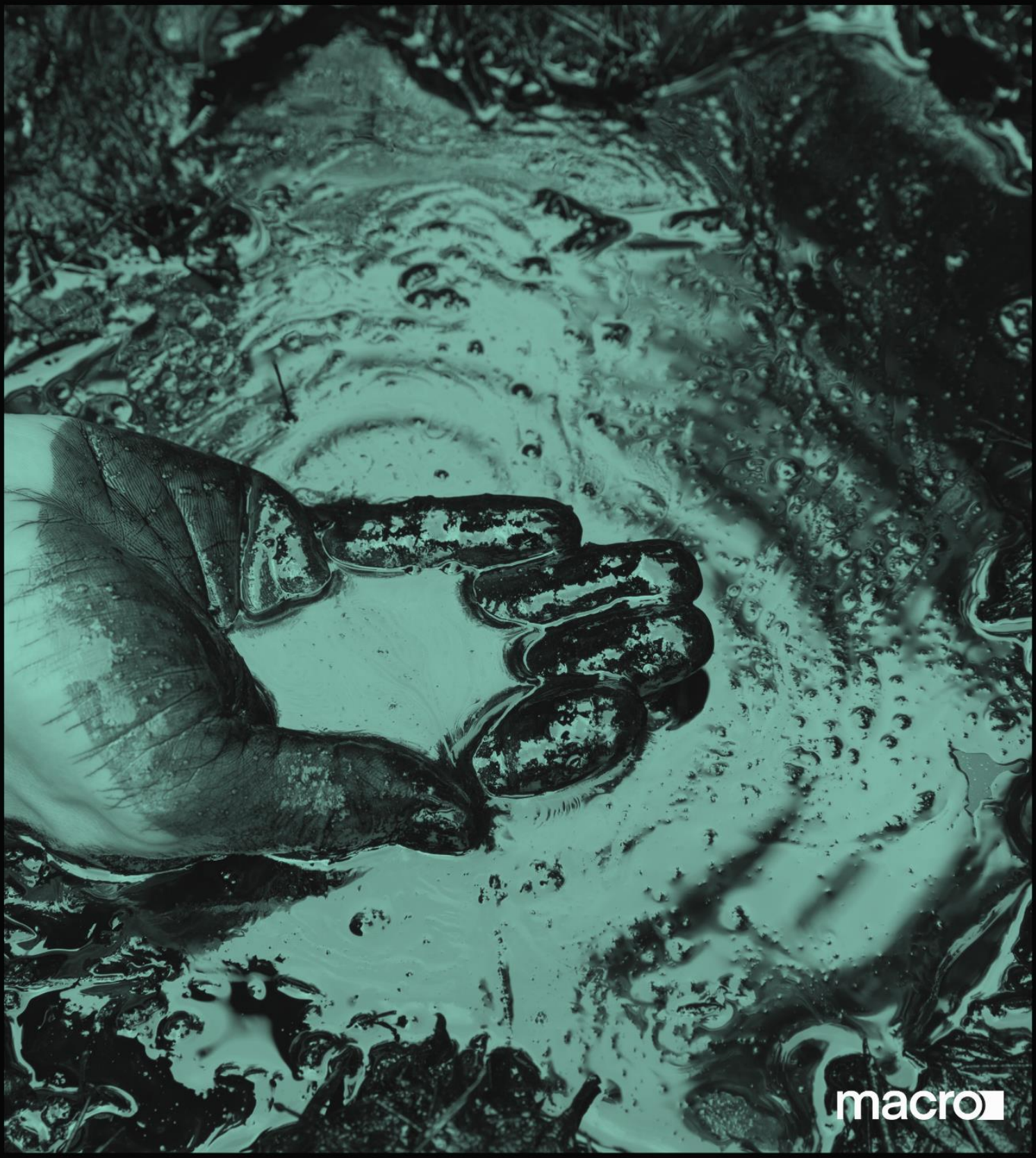
H2 CHEMISTRY · NOTES · TOPIC 11

Alkanes



Checklist:

Alkanes	Check (✓)
1. I can recall the reactions an alkane can undergo, as well as their reagents and conditions	
2. I can draw and describe the mechanism of free radical substitution, with particular reference to the initiation, propagation and termination reactions	
3. I can explain the general un-reactivity of alkanes towards polar reagents	
4. I am able to predict the possible products formed during free radical substitution, as well as their statistical probability ratio.	
5. I can explain, using the concept of stability of radicals, why isomers of alkyl halides are formed in different proportions during free radical substitution	
6. I able to recognise the environmental consequences of: a. carbon monoxide, oxides of nitrogen and unburnt hydrocarbons arising from the internal combustion engine and of their catalytic removal b. gases that contribute to the enhanced greenhouse effect	
7. I am able to recognise that petroleum, a chemical feedstock, is a finite resource and the importance of recycling	

FAQ 1 : Why are alkanes generally unreactive towards polar reagents?

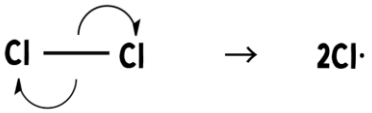
- Due to the **similarities in electronegativities** of the C and H atoms, C-C and C-H bonds are **non-polar**.
- C-C and C-H bonds are **strong** as well (B.E (C-C) = 350 kJ mol^{-1} ;B.E (C-H) = 410 kJ mol^{-1}
- Hence, alkane molecules do not contain any significant amount of **positive or negative charge** and are unreactive towards polar reagents.

FAQ 2 : Describing the Mechanism of Free Radical Substitution

- Consider the mechanism when propane is reacted with chlorine in the presence of UV light to form 1-chloropropane.

Remarks

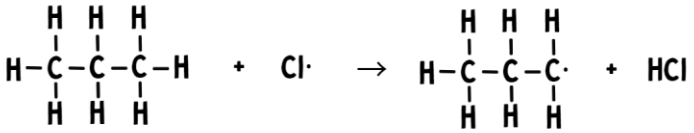
Initiation:

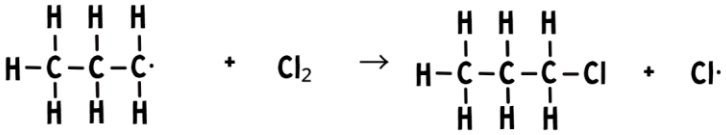


B.E (C*l*-C*l*) = 244 kJ mol^{-1} < B.E (C-H) = 410 kJ mol^{-1}

Therefore, C-H bonds are not affected during the initiation step.

Propagation:

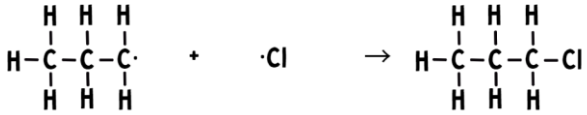


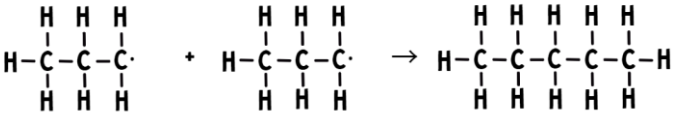


Propagation steps always produce a radical to further propagate the reaction

(The Cl· radical generated in the second step can be used to react with another propane molecule)

Termination:

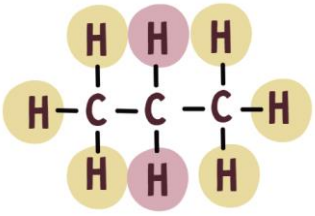
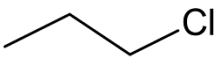
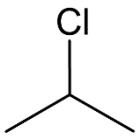




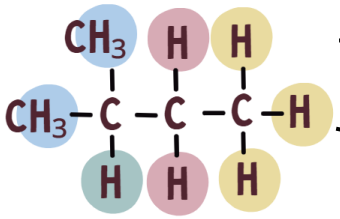
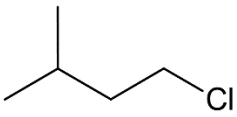
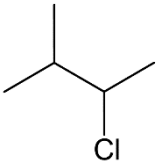
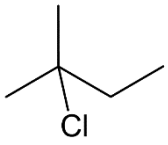
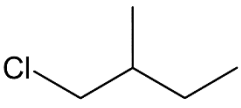
Termination steps consume radical and forms stable products, thereby termination the chain reaction.

FAQ 3 : Predicting the Statistical Ratio of Products

- When we only take into account the statistical probability of forming products, there will be 2 products formed from the reaction between propane and chlorine in the presence of UV light.

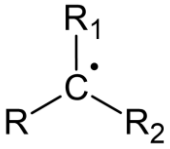
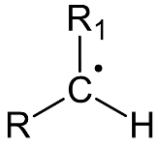
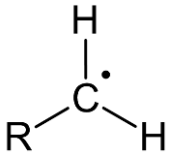
Types of Hydrogen	Products	Probability
 six 1^o hydrogens two 2^o hydrogens	If H substituted,  If H substituted, 	75% 25%

- **Example 2:** Predict the ratio of the products formed when 2-methylbutane reacts with Cl_2 under UV light.

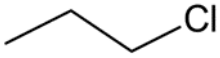
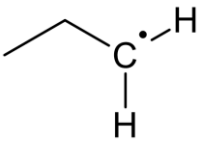
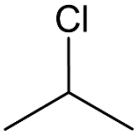
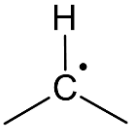
Types of Hydrogen	Products	Ratio
	If H substituted,  If H substituted,  If H substituted,  If H substituted, 	3 2 1 6

FAQ 4 : Using Stability of Radicals to Explain the Discrepancy between Statistical and Actual Ratio

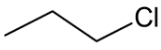
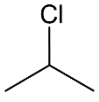
- However, when we take into account the stability of the radical intermediates, the observed ratio between the 2 products formed from the reaction between propane and chlorine will be different than the statistical ratio.
- **Concept: Stability of Radicals**

	Tertiary (3º) Radical	Secondary (2º) Radical	Primary (1º) Radical
Stability		> 	> 
Explanation	Radical intermediates are unstable (high in energy). The **more electron-donating alkyl groups** attached to the carbon radical, the more **stable the radical** and the easier it is to be formed.		

- Considering the radical intermediates leading to each product,

Products	Intermediate	Statistical Probability	Observed Probability
		**75%**	**30%**
		**25%**	**70%**

Explanation / Answering Technique

1.  is formed from a **primary** radical while  is formed from a **secondary** radical.
2. With **more electron-donating alkyl groups** attached to the carbon radical, the secondary radical will be **stabilized to a greater extent** and hence forms  at a higher proportion.

FAQ 5: Environmental Consequences of the use of Hydrocarbon (and Others)

Pollutant	Explanation	Effect
Unburnt Hydrocarbon	Due to incomplete combustion of fuel, carbon monoxide and unburnt hydrocarbon arises	Reacts with oxygen, ozone and oxides of nitrogen in the presence of sunlight to form **photochemical smog**
Carbon monoxide		Binds irreversibly with haemoglobin in blood, causing **drowsiness**, **headaches**, and even **fatality**.
Oxides of Nitrogen	At high temperature of combustion (within motor vehicles), N_2 and O_2 reacts in the following manner: $N_2(g) + O_2(g) \rightarrow 2NO(g)$ $2NO(g) + O_2(g) \rightarrow 2NO_2(g)$	Oxides of nitrogen **irritate lungs**, causes **bronchitis** and **pneumonia** Result in the formation of **photochemical smog**, which has a **harmful effect on plants.** NO_2 also catalyses the formation of SO3 from SO_2, which will dissolve in water to form **acid rain**. $NO_2(g) + SO_2(g) \rightarrow SO_3(g) + NO(g)$

Catalytic Converter

Pollutant	How It's Removed
Unburnt Hydrocarbon	$C_xH_y(g) + (x + y/4)\ O_2(g) \rightarrow xCO_2(g) + H_2O(g)$
Carbon monoxide	$2CO(g) + O_2(g) \rightarrow 2CO_2(g)$
Oxides of Nitrogen	$2NO(g) + 2CO(g) \rightarrow N_2(g) + 2CO_2(g)$