Answer all the questions below as fully as you can then check your answers

1(a) Define the term free radical.
(b) Define homolytic bond cleavage. (2 marks)

2. Explain why the reaction between methane and chlorine does not occur in the dark. (2 marks)

3. Write an equation to show the initiation step in the free radical substitution of methane by chlorine. (1 mark)

4. Write the two propagation steps for the reaction between methane and chlorine. (3 marks)

5. Explain why the propagation steps form a chain reaction. (3 marks)

6. Show how the two propagation steps combine to give the overall reaction equation. (2 marks)

7. Explain what happens in the termination step of a free radical substitution reaction. (2 marks)

8. Give two possible termination reactions for the chlorination of methane. (2 marks)

9. Explain why a mixture of products is formed when methane reacts with chlorine. (3 marks)

Explain how reaction conditions can be changed to increase the proportion of chloromethane in the product mixture.

11. Why is it incorrect to say that free radicals cancel out in the mechanism? (2 marks)

12. Describe the mechanism for the free radical substitution of methane by chlorine. (5 marks)

Answers

1(a) Define the term free radical.
(b) Define homolytic bond cleavage. (2 marks)

Answer:
(a) A free radical is a species with an unpaired electron.
(b) Homolytic bond cleavage is when a covalent bond breaks evenly, with one electron going to each atom, forming two free radicals.

2. Explain why the reaction between methane and chlorine does not occur in the dark. (2 marks)

Answer:
The reaction does not occur in the dark because ultraviolet light is needed to cause homolytic bond cleavage of Cl2 to form chlorine free radicals. Without free radicals, the chain reaction cannot start.

Question 3

3. Write an equation to show the initiation step in the free radical substitution of methane by chlorine. (1 mark)

Answer:
$Cl2 \rightarrow 2Cl\cdot$

4. Write the two propagation steps for the reaction between methane and chlorine. (3 marks)

Answer:
$Cl\cdot + CH4 \rightarrow CH3\cdot + HCl$
$CH3\cdot + Cl2 \rightarrow CH3Cl + Cl\cdot$

5. Explain why the propagation steps form a chain reaction. (3 marks)

Answer:
Each propagation step starts with a free radical and ends with a free radical. The chlorine free radical produced can react again with another methane molecule, allowing the reaction to continue.

6. Show how the two propagation steps combine to give the overall reaction equation. (2 marks)

Answer:
$CH_4 + Cl_2 \rightarrow CH_3Cl + HCl$
The free radicals are intermediates and are not shown in the overall equation.

7. Explain what happens in the termination step of a free radical substitution reaction. (2 marks)

Answer:
In termination, two free radicals react together to form a stable molecule. No new free radicals are produced, so the chain reaction stops.

8. Give two possible termination reactions for the chlorination of methane. (2 marks)

Answer:
$Cl\cdot + Cl\cdot \rightarrow Cl_2$
$CH_3\cdot + Cl\cdot \rightarrow CH_3Cl$
$CH_3\cdot + CH_3\cdot \rightarrow C_2H_6$

9. Explain why a mixture of products is formed when methane reacts with chlorine. (3 marks)

Answer:
Chloromethane formed in the reaction can also undergo further substitution. As the reaction continues, hydrogen atoms are replaced one at a time by chlorine atoms, producing a mixture of products.

Question 10 – Reaction conditions (3 marks)

Explain how reaction conditions can be changed to increase the proportion of chloromethane in the product mixture.

Answer:
Using a large excess of methane increases the chance that a chlorine free radical reacts with methane rather than with substituted products, favouring chloromethane.

11. Why is it incorrect to say that free radicals cancel out in the mechanism? (2 marks)

Answer:
Free radicals do not cancel out. They are intermediates that are formed in one step and used up in another.

12. Describe the mechanism for the free radical substitution of methane by chlorine. (5 marks)

Answer:
UV light causes homolytic bond cleavage of Cl_2 to form chlorine free radicals.
A chlorine free radical reacts with methane to form a methyl free radical and HCl.
The methyl free radical reacts with Cl_2 to form chloromethane and regenerate a chlorine free radical.
The reaction continues as a chain reaction.
Termination occurs when two free radicals react together to form a stable molecule.