S5 CHEMISTRY DISCUSSION

Uganda Advanced Certificate of Education
CHEMISTRY

Item 1: During a chemistry lesson on gaseous reactions, learners were asked to investigate an unknown gaseous hydrocarbon, X. Sharon conducted an experiment where she exploded 20 cm^3 of hydrocarbon X with 100 cm^3 of excess oxygen. After cooling, the total gas volume was 90 cm^3, and after passing the mixture through aqueous potassium hydroxide, the volume reduced to 50 cm^3.

Hydrocarbon X burns in oxygen according to the following equation:-

$$C_xH_{y(g)} + (x+\frac{y}{4})\,O_{2(g)} \longrightarrow XCO_{2(g)} + \frac{y}{2}H_2O_{(l)}$$

Sharon is unsure how to use these results to identify hydrocarbon X. She presents her findings to the class for interpretation.

TASKS: As a chemistry student, Help Sharon to;

a) Understand what caused the drop in volume after explosion, and why did it reduce further after treatment with potassium hydroxide?

After explosion: *Hydrocarbon reacted with oxygen to produce carbon dioxide and water vapour. Upon cooling, water vapour condensed to liquid, reducing the gas volume.*

After passing through aqueous KOH: *Potassium hydroxide solution absorbs carbon dioxide (forms potassium carbonate), so remaining volume after absorption is due to unreacted oxygen.*

b). Calculate the volumes of carbon dioxide and oxygen that reacted.

$$C_xH_{y(g)} + (x+\frac{y}{4})\,O_{2(g)} \longrightarrow XCO_{2(g)} + \frac{y}{2}H_2O_{(l)}$$

Volume of hydro-carbon = 20cm^3

Volume of excess oxygen = 100cm^3

Initial gas volume before ignition = 20 + 100 = 120 cm^3.

*Volume after cooling = 90 cm^3 (**volume of carbon dioxide +unreacted oxygen**).*

Volume after KOH = 50 cm^3.

Volume of CO_2 formed = 90 - 50 = 40 cm^3.

Volume of unreacted oxygen = 50cm^3

Volume of O_2 reacted = 100 - 50 = 50 cm^3.

c). Deduce the molecular formula and molecular mass of hydrocarbon X.

Hydrocarbon : Carbon

Volume of hydrocarbon x moles of CO_2 = Volume of carbon dioxide produced

$$20 \times x = 40$$

$$x = \frac{40}{20} = 2$$

Molecular formular = C_xH_y

Molecular formular = C_2H_2

Molecular mass = (2x12) + (2x1)

Volume of hydrocarbon x moles of O_2 = Volume of reacted oxygen

$$(x+\frac{y}{4}) \times 20 = 50$$

$$(2+\frac{y}{4}) \times 20 = 50$$

$$2+\frac{y}{4} = 2.5$$

$$8 + y = 10$$

y = 2

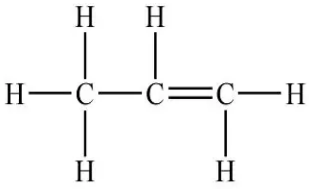
d) Help Sharon to understand the impact of the gaseous product produced and how it can be mitigated.

- The gaseous product (CO_2) traps heat in the earth's atmosphere, contributing to global warming and climate change this can be mitigated through the use of clean /renewable energy(solar, wind), promoting afforestation.

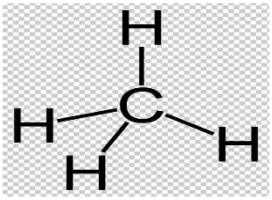
Item 2: A group of forensic chemists are investigating organic substances they found at certain suspected illegal chemical dump. analysis gave them the molecular formula of the two compounds as M(C_3H_6)and N (CH_4).To gather more information about the compounds they also need to know the nature of the two compounds and their chemical reactivity. They are aware that you have some knowledge on organic chemistry and have come to you for advice.

Task: As a chemistry student help them to

i)Write the structural formulae and state the functional groups present in the organic compounds.



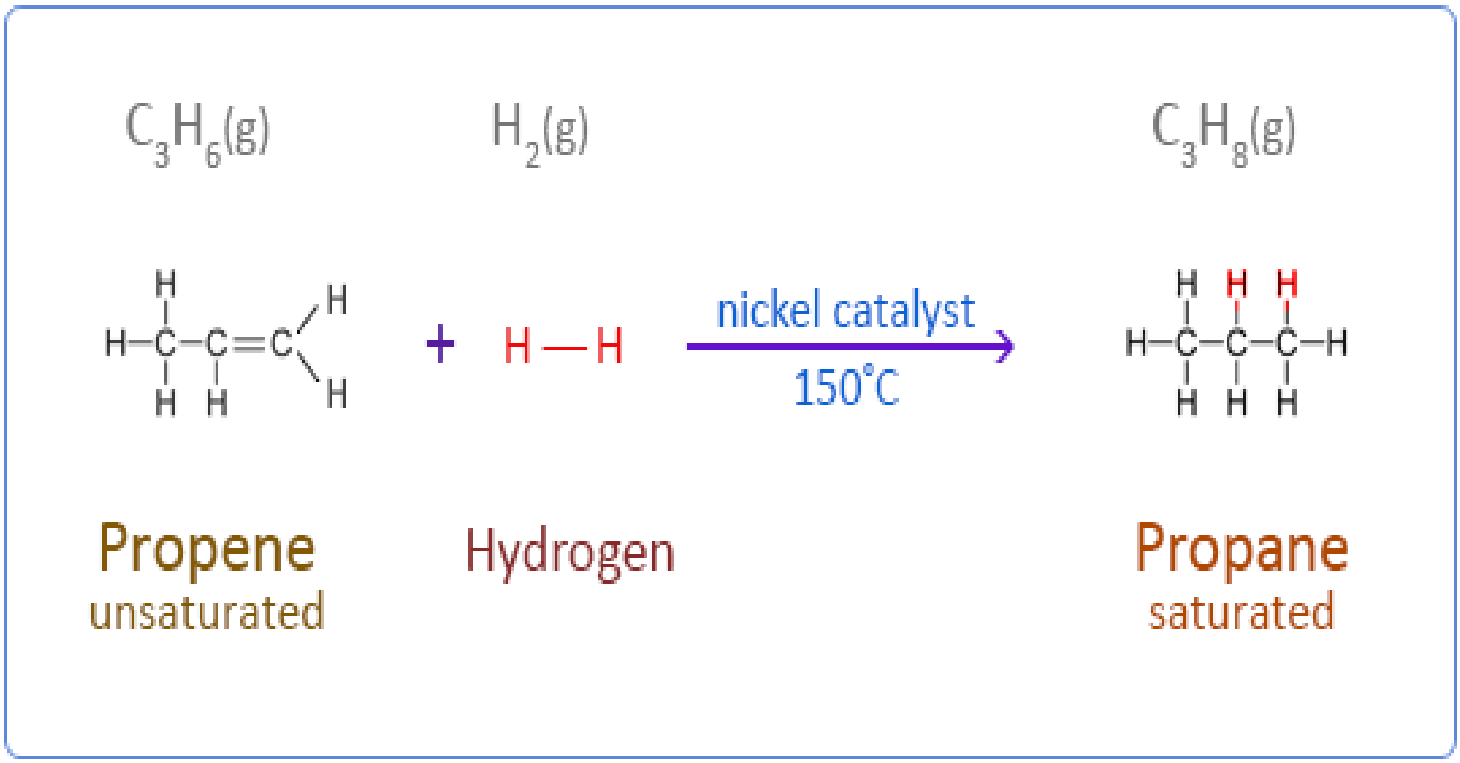
Functional group – [C=C ***Double bond***]



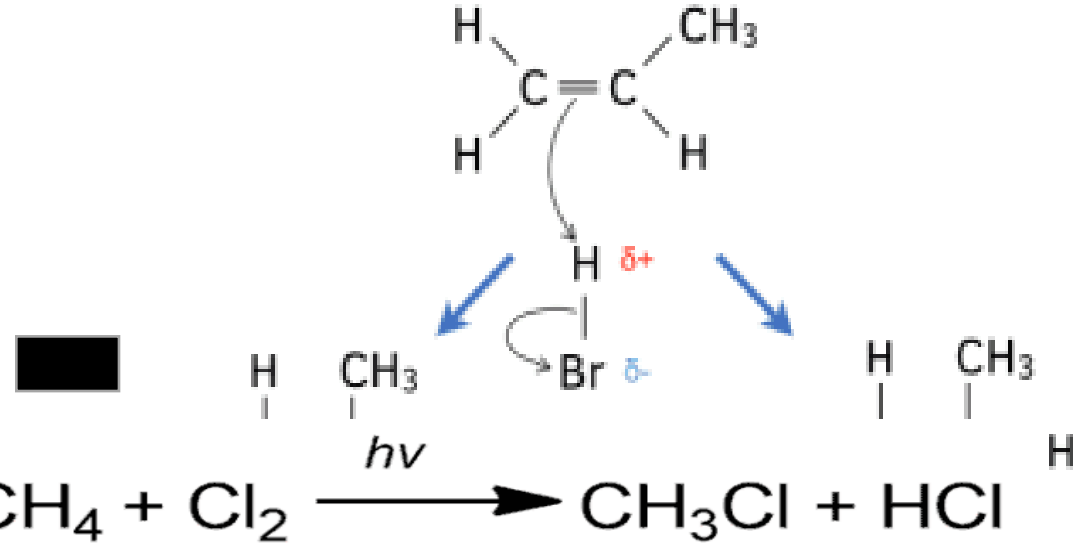
Functional group –[C–H ***Single bond***]

ii)Predict the reaction and write the mechanisms for the reaction of;

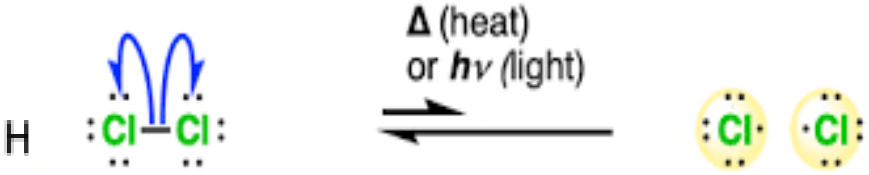
a) M with hydrogen gas



b) N with Hydrogen bromide

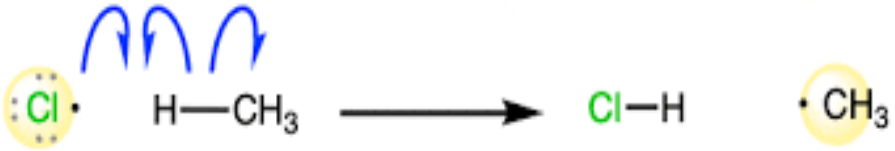


Initiation



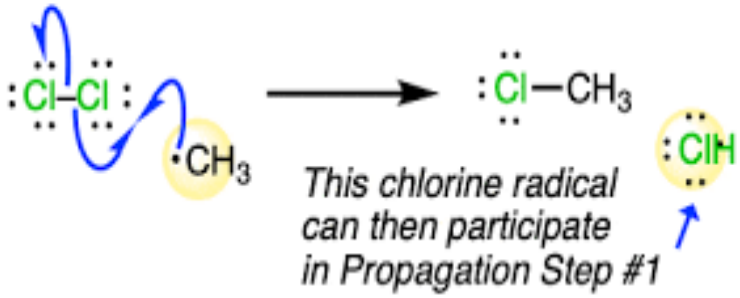
Form	Break
	Cl—Cl

Propagation #1



Form	Break
Cl–H	C–H
103 kcal/mol	104 kcal/mol

Propagation #2



Form	Break
C–Cl	Cl–Cl
81 kcal/mol	58 kcal/mol

Termination

Form
C–Cl

(iii) Help the students to analyze the impacts of one of the compounds to the environment.

- Methane contributes to **climate change** and **ground-level ozone formation**; these impacts can be reduced by **capturing emissions from waste sources**, repairing gas leaks, regulating agricultural methane, and cutting NO_x emissions.
- Propene causes ***photochemical smog and secondary organic aerosols***; mitigation includes controlling industrial VOC emissions, improving vehicle fuel standards, adopting cleaner processes, and enforcing VOC limits.

Item 3: During a classroom discussion on energy changes in chemical reactions, the teacher asked learners to suggest indirect ways of determining enthalpy changes for reactions that cannot be measured directly in the laboratory. One learner, Joel, proposed using Hess's Law.

To apply this, the class was asked to determine the standard enthalpy of formation (ΔHf^{o}) of methane gas (CH_4). They are provided with the following standard enthalpy changes of combustion:

$\Delta H_c^{o}[\ CH_4] = -890$ KJ/mol

$\Delta H_c^{o}[\ H_2] = -286$ KJ/mol

$\Delta H_c^{o}[\ C_{(Graphite)}] = -393$KJ/mol

However, some learners are confused about how these combustion reactions can be used to determine the enthalpy of formation of methane using Hess's Law.

Task: As a chemistry student, help the learners to:-

a) Understand the meaning of enthalpy of formation

Enthalpy of formation is the heat change when 1 mole of a compound is formed from its elements in standard states under standard conditions.

b) Using Hess's Law, construct an energy cycle or equation arrangement that links the combustion reactions to the formation reaction of methane:

Energy cycle arrangement:

Formation: $C_{(graphite)} + 2H_{2(g)} \rightarrow CH_{4(g)}$

Combustion reactions:

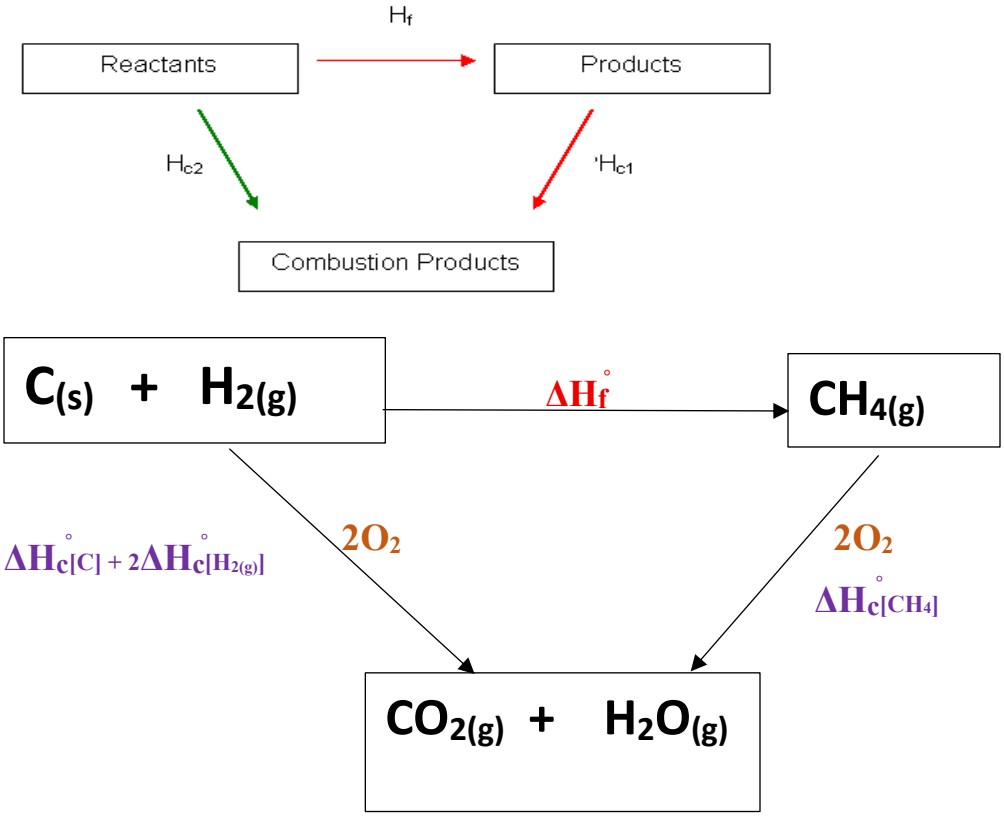
$CH_4 + 2O_2 \rightarrow CO_2 + 2H_2O$ $\Delta Hc = -890$ kJ/mol

$H_2 + \frac{1}{2}O_2 \rightarrow H_2O$ $\Delta Hc = -286$ kJ/mol

$C + O_2 \rightarrow CO_2$ $\Delta Hc = -393$ kJ/mol

$\Delta Hf°(CH_4) = [\Delta Hc(C) + 2\Delta Hc(H_2)] - \Delta Hc(CH_4)$

OR



c). Use the provided data to calculate the standard enthalpy of formation (ΔHf^{o}) of methane.

$\Delta Hf°(CH_4) + \Delta Hc(CH_4) = \Delta Hc(C) + 2\Delta Hc(H_2)]$

$\Delta Hf°(CH_4) = [\Delta Hc(C) + 2\Delta Hc(H_2)] - \Delta Hc(CH_4)$

$\Delta Hf° = [-393 + 2(-286)] - (-890) =$ ***-75 kJ/mol***

d). Comment on the sign of the enthalpy of formation value obtained. What does it indicate about the stability of methane compared to its elements?

*Negative ΔHf° means formation is **exothermic**; methane is more stable than its separate elements.*

Item 4:

A chemistry student is studying the properties and reactions of the Group 2 elements (alkaline earth metals). The student is particularly interested in understanding the trends in these elements.

As part of the student's research, they come across a company that uses magnesium (Mg) in the production of fireworks and flares. The company is considering replacing Mg with another Group 2 element, calcium (Ca), to reduce costs.

However, the student is concerned that using Ca may not produce the same bright light and high temperature as Mg. The student decides to investigate the reactions of Mg and Ca with water, oxygen, acids, and halogens to determine which element is more suitable for the company's needs.

TASK: As a chemistry student, who has studied about group 2 elements,

(a) Explain the trends in atomic radius, electronegativity, and first ionization energy of the Group 2 elements. How do these trends affect the reactivity of these elements? (8mks)

(b) Write and explain the reactions of Mg and Ca with:

- ✓ Water
- ✓ Oxygen
- ✓ Dilute hydrochloric acid (HCl)
- ✓ Chlorine (Cl2)

Which element is more suitable for the company's needs? (6mks)

(c) Discuss the general uses of the Group 2 elements in various industries, (6mks)

RESPONSES

a) Trends:

Atomic radius increases down group, electronegativity decreases, ionization energy decreases.

Reactivity increases down the group.

b) Reactions:

With water: Mg reacts slowly with cold water, faster with steam; Ca reacts readily with cold water.

With oxygen: $2Mg + O_2 \rightarrow 2MgO$; $2Ca + O_2 \rightarrow 2CaO$.

With dilute HCl: $Mg + 2HCl \rightarrow MgCl_2 + H_2$; $Ca + 2HCl \rightarrow CaCl_2 + H_2$.

With Cl_2: $Mg + Cl_2 \rightarrow MgCl_2$; $Ca + Cl_2 \rightarrow CaCl_2$.

Suitability: Mg produces brighter white light; Ca produces orange-red flame.

c) Uses: Mg in fireworks, flares, alloys; Ca in cement, steel production.

Item 5: A company that manufactures conductors and fireworks considers periodic properties of elements listed ; lithium ,sodium and potassium. This company seeks to hire professionals who will help to give necessary information on how periodic properties affect the conductivity and formation of fire works so as to determine the best metal to use.

Task ;

As a chemistry student ,make a write-up showing how ionization energy and electro-positivity of the listed metals enable them to conduct electricity, and hence determine which one is better at forming fire works and conductors

RESPONSES

Li, Na, K conductivity & fireworks

Ionization energy decreases down group, electro positivity increases, making metals more reactive.

All conduct electricity due to delocalized electrons; K is most reactive, Na balances cost and performance.

Fireworks: Li – red flame, Na – yellow flame, K – lilac flame.

****END****

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For solutions, search on YouTube "*Nyirimbibi Isaac-chemistry connect***"**