

1.4.1 Fuel processing, hazards and life-cycle carbon

Name: _____ Class: _____ Date: _____ **Total: 24 marks**

KEY WORDS hazard • risk • carbon neutrality

Objective

Choose safer organic methods, balance fuel-processing reactions and evaluate carbon-neutral claims using a stated boundary. Original practice for Topic 4.

1 Key knowledge and worked examples

■ A hazard needs a matching control

Flammability is a hazard; the risk depends on the amount, ignition sources and procedure. Smaller quantities, an appropriate electric heater instead of a naked flame, and a less hazardous suitable solvent can reduce different risks.

■ Fuel processing changes molecules in different ways

Fractional distillation is physical separation. Cracking can give $\text{C}_{10}\text{H}_{22} \rightarrow \text{C}_8\text{H}_{18} + \text{C}_2\text{H}_4$. Reforming can give hexane $\rightarrow$ cyclohexane + hydrogen: $\text{C}_6\text{H}_{14} \rightarrow \text{C}_6\text{H}_{12} + \text{H}_2$. Both chemical equations conserve carbon and hydrogen.

Carbon neutrality concerns net carbon dioxide over a defined life cycle. Hydrogen produces water when used, but production from fossil fuels can emit carbon dioxide. Bioethanol growth absorbs carbon dioxide; fertiliser production, processing and transport also matter.

2 Practice

2.1 Distinguish hazard from risk for a flammable organic solvent. Suggest two different controls and explain what risk each reduces. [4]

2.2 Complete and balance: $\text{C}_{12}\text{H}_{26} \rightarrow \text{C}_8\text{H}_{18} + \dots$. State which product is an alkene and why this is a chemical change. [3]

2.3 Classify the conversion of ethene to poly(ethene), methane to chloromethane, ethanol to ethanal, and ethene to ethane as polymerisation, substitution, oxidation or reduction. [4]

3 Exam-style questions

3.1 Compare the problems caused by CO, sulfur dioxide, nitrogen oxides and carbon particulates from fuel use. Explain why removing sulfur from a fuel does not prevent nitrogen oxide formation in a hot engine. [5]

3.2 One litre of a biofuel absorbs 1.60 kg CO₂ during crop growth. Its cultivation and processing emit 0.45 kg, distribution emits 0.10 kg and combustion emits 1.60 kg. Calculate net emissions within this boundary. Evaluate the claim that the fuel is carbon neutral, including one excluded factor. ^[4]

3.3 A refinery can reform hexane to benzene and hydrogen. Balance $\text{C}_6\text{H}_{14} \rightarrow \text{C}_6\text{H}_6 + \text{H}_2$. Explain why this process is not fractional distillation, and give one sustainability advantage and one limitation of using its hydrogen as a fuel. ^[4]

Solutions

Original authored marking; accept equivalent evidence-based evaluations.

2.1 Hazard is potential to cause harm; risk concerns likelihood and severity during actual use. Smaller quantities reduce the possible scale of a fire; an appropriate electric heater instead of a naked flame reduces ignition risk. Accept a suitable less flammable solvent or other justified controls. Ventilation addresses vapour exposure but does not alone remove ignition risk.

2.2 $\text{C}_{12}\text{H}_{26} \rightarrow \text{C}_8\text{H}_{18} + \text{C}_4\text{H}_8$. In the stated cracking model, C_4H_8 is the alkene product; bonds change and new substances form, unlike physical separation. Its formula alone would not distinguish an unknown alkene from a cycloalkane.

2.3 Polymerisation; substitution; oxidation; reduction respectively. Adding hydrogen to ethene reduces the organic molecule.

3.1 CO is toxic because it binds strongly to haemoglobin and reduces oxygen transport. SO_2 and nitrogen oxides contribute acidity/acid deposition. Carbon particulates damage air quality and can harm respiratory health. Nitrogen oxides can form from atmospheric nitrogen and oxygen at high engine temperatures even if the fuel contains no sulfur.

3.2 Net $\text{CO}_2 = 0.45 + 0.10 + 1.60 - 1.60 = 0.55$ kg per litre. It is not carbon neutral within this boundary because net emissions are positive. Land-use change, soil carbon changes or machinery manufacture could change the full-life-cycle result. Crop uptake cancels the stated combustion emission only.

3.3 $\text{C}_6\text{H}_{14} \rightarrow \text{C}_6\text{H}_6 + 4\text{H}_2$. Reforming changes chemical bonds; fractional distillation separates existing substances by boiling range. Hydrogen forms water rather than CO_2 at its point of use, but this hydrogen originated from a fossil feedstock and processing consumes energy, so use-stage emissions alone do not show life-cycle carbon neutrality.