9.3 Combustion products, pollutants and appropriate controls

Name: _____ Class: _____ Date: _____ **Total: 32 marks**

KEY WORDS incomplete combustion • acid rain • particulates

Objective

Predict products from fuel elements and conditions, then link each pollutant to its effects and suitable control. Original practice and authored marking guidance for 4.9.3.1–4.9.3.2, both tiers.

1 Key knowledge and worked examples

Complete combustion of a **pure hydrocarbon** with sufficient oxygen gives CO_2 and water. Limited oxygen can cause **incomplete combustion** , producing CO and carbon particles as well as some CO_2/water. **Particulates** also include unburned hydrocarbons. Sulfur in fuel burns to SO_2. High-temperature engines can form NO_x from nitrogen and oxygen in air, even with sulfur-free fuel.

CO is toxic, colourless and odourless: smell is not a test. SO_2/NO_x cause breathing problems and **acid rain** . Particles harm health and cause **global dimming** by reducing sunlight reaching the surface. This differs from greenhouse gases absorbing outgoing infrared.

Worked prediction. Pure hydrogen in oxygen forms water, not CO_2: the reactants contain no carbon. Replacing sulfur-containing petrol with sulfur-free petrol reduces SO_2 but not necessarily NO_x, because nitrogen can come from air.

Worked control. More complete combustion reduces CO/soot but still makes CO_2. Particle filters target particles; a gas can pass through. Exhaust treatment must match the pollutant and chemistry. With supplied calcium oxide, $CaO + SO_2 \rightarrow CaSO_3$; making sulfate also needs oxygen. A catalytic converter can reduce NO using CO, producing nitrogen and CO_2; it is not simply a universal gas filter.

2 Practice

2.1 Name the two products of complete combustion of a pure hydrocarbon in oxygen.[2]

2.2 Which pollutant causes acid rain together with NO_x? [1]

2.3 Give a harmful effect of carbon monoxide and explain why relying on smell is unsafe. [2]

2.4 Predict the combustion product of pure hydrogen in oxygen. Explain why no carbon dioxide forms. [2]

3 Exam-style questions

3.1 Explain why incomplete hydrocarbon combustion occurs. Give one gaseous and one solid pollutant it may produce, with one harmful effect of each. [5]

3.2 Explain how sulfur dioxide forms from a fuel. Exhaust is treated with calcium oxide. Complete the supplied reaction: $CaO + SO_2 \rightarrow$ _____. Explain why claiming $CaSO_4$ forms from only these two reactants is wrong. [4]

3.3 Oxides of nitrogen form in a high-temperature engine using pure fuel containing no nitrogen. Explain their source and formation, then give one health effect and one environmental effect. [4]

3.4 A town installs particle filters and switches to sulfur-free fuel. Evaluate "all breathing problems and climate effects from engines are now removed". Give two benefits and two remaining pollutant concerns, with reasons. [4]

3.5 Distinguish global dimming from greenhouse warming using the type/direction of radiation and the material responsible. [4]

3.6 A converter uses the supplied reaction $2CO + 2NO \rightarrow 2CO_2 + N_2$. Check atom conservation, name the two harmful gases removed, and explain why it does not remove all climate impact. [4]