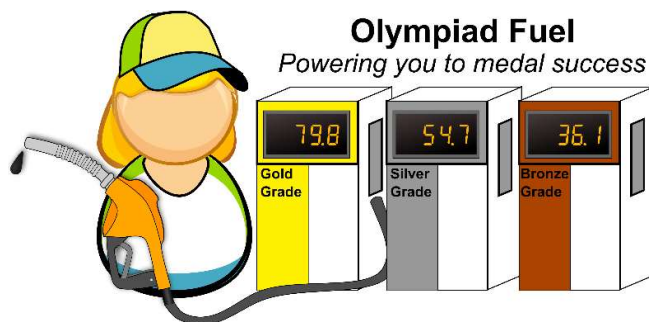


Q1 This question is about E10 petrol

To help tackle the causes of climate change, in September 2021 the UK government changed the standard petrol grade at fuel pumps from E5 to E10 petrol. These E values refer to the percentage of ethanol in the ethanol-hydrocarbon fuel mixture. It has been argued that the change from E5 to E10 was one contributing factor to the petrol shortage in October 2021 as retailers attempted to remove their stock supplies of E5.



E values and octane numbers are both displayed on petrol pumps. There is only a small proportion of the straight chain isomer of octane in petrol as this tends to “knock” in the engine. Knocking is where the fuel ignites prematurely and this reduces engine efficiency. Branched chain isomers of octane knock much less and a lot of these are found in petrol. One major isomer is 2,2,4-trimethylpentane.

(a) Draw the skeletal formula of 2,2,4-trimethylpentane.

Blending ethanol into fuel mixtures such as in E5 and E10 also reduces knocking. Ethanol is a biofuel and is often produced by fermenting sugar from crop plants. The plants capture carbon dioxide from the atmosphere and convert this into sugars such as glucose, $C_6H_{12}O_6$, through photosynthesis.

(b) Write the equation for the formation of glucose in photosynthesis from carbon dioxide.

The anaerobic fermentation of glucose produces ethanol and carbon dioxide.

(c) Write the equation for the anaerobic fermentation of glucose.

One of the characteristics of an effective fuel is the amount of energy it releases, or its enthalpy of combustion. One method to determine this is to use average bond enthalpies. Some average bond enthalpies are given below.

Bond	Average bond enthalpy / kJ mol^{-1}
C–C	347
C–H	413
O=O	498
C–O	358
C=O	805
O–H	464

When calculated by this method, all the different isomers of octane have the same value.

(d) Calculate the enthalpy of combustion of an isomer of octane.

Assume that 1 litre of E10 fuel contains 100 mL of ethanol and 900 mL of octane isomers, and that 1 litre of E5 fuel contains 50 mL of ethanol and 950 mL of octane isomers. The density of pure ethanol is 0.789 g cm^{-3} and the density of pure octane isomers is 0.703 g cm^{-3} . You can assume that there is no volume change on mixing.

The enthalpy of combustion of ethanol using average bond enthalpies is $-1276 \text{ kJ mol}^{-1}$.

- (e) For both E5 and E10 fuels, calculate the energy, in kJ, released when 1 litre of the fuel is burnt.

If you did not get an answer for part (d) then you may use a value of $-6666 \text{ kJ mol}^{-1}$ for the enthalpy of combustion of octane isomers in this calculation.

- (f) Taking the energy released from burning 1 litre of E5 as 100%, calculate the percentage of the energy released from burning 1 litre of E10 fuel.

All the carbon dioxide released by the combustion of ethanol is offset by the carbon dioxide captured when the plants are grown. As such, the contribution from the ethanol is not counted when the CO_2 footprints of the E5 and E10 fuels are compared.

- (g) Taking the CO_2 produced from burning 1 litre of E5 fuel as 100%, calculate the percentage of CO_2 produced from burning 1 litre of E10 fuel. Consider only CO_2 formed from the combustion of octane isomers.