2. This question is about the unnecessary production of carbon dioxide

Outdoor flames, such as patio heaters and the Olympic flame, contribute to global warming. This is not only due to the heat released, but also due to the carbon dioxide produced from the combustion of hydrocarbons.

Most patio heaters are powered by small cylinders of propane gas. A typical patio heater designed to produce 15 kW of energy runs from a cylinder containing 13 kg of propane. A 'completely full' cylinder at a pressure of 140 psi (9.52 atmospheres) is in fact only filled to about 87% capacity with liquid propane, the remaining volume being taken up by propane vapour. The standard enthalpy change of combustion of propane is –2220 kJ mol^{-1}.

Assume 1 mole of a gas occupies 24 dm^3 under the conditions of this question.

(a) **i)** Calculate the number of moles of propane contained in a cylinder.

ii) Calculate the mass of carbon dioxide produced when all of the propane in a cylinder is burnt completely.

iii) Calculate the total amount of heat energy released by combustion of all the propane in a cylinder.

i**v)** Calculate the rate at which propane must leave the cylinder (in $cm^3\ s^{-1}$) to produce 15 kW (ie 15 kJ s^{-1}).

v) Estimate the equilibrium pressure when the cylinder is only 'half full'.

Because pure propane gas is odourless, small amounts of another compound are usually added so that gas leaks can be detected. An example of such an odorant is ethyl mercaptan (ethanethiol, C_2H_5SH); this is chosen since the human nose can detect its presence at levels of only about 0.02 ppb (parts per billion).

(b) **i)** Draw a diagram to show how the atoms are bonded together in ethyl mercaptan and predict the bond angle around the sulphur atom.

ii) Calculate the mass of ethyl mercaptan which must be added to 13 kg of propane to produce 0.02 molecules of it per billion (10^9) molecules of propane.

The Olympic flame on top of the Bird's Nest Stadium which burned throughout the Beijing Olympics consumed 6000 m^3 of methane per hour and was kept alight for 16 days.

(c) Calculate the total mass of carbon dioxide produced from the flame during the Olympics, assuming complete combustion.