**34.10 A dry product analysis of the flue gas after butane is burned in air shows that the products contain 5.6% $O_2$ and 10.2% $CO_2$. How much excess air was in the reaction?**

A. 8%

B. 26%

C. 34%

D. 40%

Start by writing the stoichiometric reaction for butane burned in air. The formula shown in the table Combustion Reactions of Common Fuel Constituents omits nitrogen because it does not participate in the combustion process, however nitrogen does appear in the dry product analysis. Water is not included in the dry product analysis. Include 3.77 molecules of nitrogren for every molecule of oxygen as this is the naturally occurring ratio in atmospheric air. Note the air to fuel ratio on a volume or molar basis is 6.5 when there is no excess air.

$$C_4H_{10} + 6.5\,(O_2 + 3.77N_2) \rightarrow 4CO_2 + 5H_2O + 24.5N_2 \;\; (stoichiometric)$$

Write another reaction for the excess air scenario and intially include variables before each product or reactant to account for unknown values. Also include an oxygen product since excess $O_2$ will be provided and remain unburned.

$$aC_4H_{10} + b\,(O_2 + 3.77N_2) \rightarrow cCO_2 + dH_2O + eO_2 + fN_2$$

Consider the products, ignoring water as it is omitted from the dry product analysis, and use the percentages given as the number of moles of each product. Since the dry products must add to 100%, calculate the moles of nitrogen.

$$c = 10.2$$

$$e = 5.6$$

$$c + e + f = 100$$

$$f = 100 - c - e = 100 - 10.2 - 5.6 = 84.2$$

Balance the carbon.

$$4a = c$$

$$a = \frac{c}{4} = \frac{10.2}{4} = 2.55$$

Balance the hydrogen.

$$10a = 2d$$

$$d = 5a = 5\,(2.55) = 12.75$$

Balance the oxygen.

$$2b = 2c + d + 2e$$

$$b = \frac{2c + d + 2e}{2} = \frac{2\,(10.2) + 12.75 + 2\,(5.6)}{2} = 22.2$$

Check the nitrogren balance. Expect a small amount of error due to rounding.

$$2\,(3.77)\,b = 2f$$

$$2\,(3.77)\,(22.2) = 2\,(84.2)$$

$$167.4 \approx 168.4\ \checkmark$$

Find the air to fuel ratio on a molar basis for the reaction with excess air.

$$\frac{air}{fuel} = \frac{b}{a} = \frac{22.2}{2.55} = 8.71$$

Compare the air to fuel ratio obtained with the original stoichiometric reaction and calculate the excess as a percentage.

$$excess\,air = \frac{8.71 - 6.5}{6.5} = 34\%$$

**Answer C**