

Course.

Environmental Chemistry  
CE 463/563

Title.

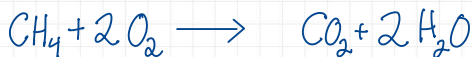
the Atmosphere

Date.

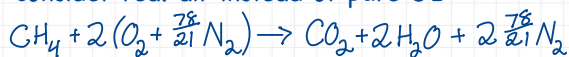
Mo Tu We Th Fr Sa Su

Determine the AFR needed to yield 7% oxygen in the exhaust gases from the combustion of natural gas ( $\text{CH}_4$ ).

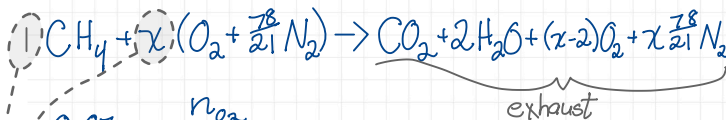
### Basic Balanced Combustion



consider real air instead of pure  $\text{O}_2$



But we want excess



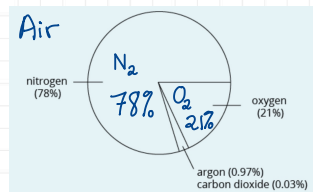
$$0.07 = \frac{n_{\text{O}_2}}{n_{\text{O}_2} + n_{\text{H}_2\text{O}} + n_{\text{O}_2} + n_{\text{N}_2}}$$

$$0.07 = \frac{x-2}{1+x+(x-2)+x\frac{78}{21}}$$

$$0.07 \left[1+x\left(1+\frac{78}{21}\right)\right] = x-2$$

$$x = 3.08$$

$$\text{AFR} = \frac{\text{mass air}}{\text{mass fuel}} = \frac{n_{\text{air}} \text{ MW}_{\text{air}}}{n_{\text{fuel}} \text{ MW}_{\text{fuel}}} = \frac{3.08 (22.28)}{1 (16.05)} = 4.28$$



| 6               | 7                 | 8               |
|-----------------|-------------------|-----------------|
| <b>C</b>        | <b>N</b>          | <b>O</b>        |
| Carbon<br>12.01 | Nitrogen<br>14.01 | Oxygen<br>16.00 |

| 1                 |
|-------------------|
| <b>H</b>          |
| Hydrogen<br>1.008 |

$$\begin{aligned} C &= 12.01 \times 1 \\ H &= 1.01 \times 4 \\ &= 16.05 \text{ g/mol} \end{aligned}$$

$$\begin{aligned} &0.21(2 \times 16) + 0.78(2 \times 14.01) \\ \text{MW}_{\text{air}} &= 22.28 \text{ g/mol} \end{aligned}$$

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Determine the volume fraction of water in air at 30°C and 45% RH.

$$VP_{(H_2O)}(30^\circ C) = \frac{31.824 \text{ mmHg}}{760 \text{ mmHg}} \text{ atm}$$

$$RH = \frac{P_{H_2O}^{actual}}{VP_{H_2O}(T)}$$

$$0.45 = \frac{P}{4.187 \times 10^{-2}} \rightarrow P = 0.45(4.187 \times 10^{-2}) = 1.884 \times 10^{-2}$$

$$\text{assume } P_{total} = 1 \text{ atm} \rightarrow y = \frac{1.884 \times 10^{-2}}{1 \text{ atm}} = 0.0188$$

$$\rightarrow 1.9\%$$

#### Vapor Pressure of Water [0 – 100°C]

| Temp (°C) | VP (mmHg) | Temp (°C) | VP (mmHg) |
|-----------|-----------|-----------|-----------|
| 0.0       | 4.579     | 37.5      | 48.364    |
| 2.5       | 5.486     | 40.0      | 55.324    |
| 5.0       | 6.543     | 42.5      | 63.13     |
| 7.5       | 7.775     | 45.0      | 71.88     |
| 10.0      | 9.209     | 50.0      | 92.51     |
| 12.5      | 10.87     | 55.0      | 115.04    |
| 15.0      | 12.788    | 60.0      | 149.38    |
| 17.5      | 14.997    | 65.0      | 187.54    |
| 20.0      | 17.535    | 70.0      | 233.7     |
| 22.5      | 20.44     | 75.0      | 289.1     |
| 25.0      | 23.756    | 80.0      | 355.1     |
| 27.5      | 27.535    | 85.0      | 433.6     |
| 30.0      | 31.824    | 90.0      | 525.76    |
| 32.5      | 36.683    | 95.0      | 633.9     |
| 35.0      | 42.175    | 100.0     | 760       |

To convert pressure to atmospheres, divide by (760 mmHg/ atm)

Interpolate with the following equation:

$$VP_{water} = 7 \times 10^{-6} * T^4 - 0.0002 * T^3 + 0.0222 * T^2 + 0.2244 * T + 4.579 \quad [0^\circ C < T < 100^\circ C]$$

Where: VP is in mmHg, and  
T is in °C.

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Calculate the wind speed at the top of city tower (90 m) if the atmosphere is stability class D and the 10m wind speed is 8mph.

downtown = urban

|   | wind  | altitude |
|---|-------|----------|
| a | 8 mph | 10 m     |
| b | ?     | 90 m     |

$$\frac{u_b}{u_a} = \left( \frac{z_b}{z_a} \right)^p$$

$$\frac{u}{8 \text{ mph}} = \left( \frac{90}{10} \right)^{0.25}$$

$$u = 8 \text{ mph} (9)^{0.25} = 13.86 \text{ mph}$$

14 mph

TABLE 12-15

Exponent  $p$  Values for Rural and Urban Regimes

| Stability Class | Rural | Urban | Stability Class | Rural | Urban |
|-----------------|-------|-------|-----------------|-------|-------|
| A               | 0.07  | 0.15  | D               | 0.15  | 0.25  |
| B               | 0.07  | 0.15  | E               | 0.35  | 0.30  |
| C               | 0.10  | 0.20  | F               | 0.55  | 0.30  |

Source: User's Guide for ISC3 Dispersion Models, Vol. II, EPA-454/B-95-003b, U.S. Environmental Protection Agency, September, 1995.

You're a low-budget meteorologist. Instead of a radiosonde on a weather balloon (which can capture measurements of the whole atmospheric column) you attach a temperature probe to a kite and take the following measurements.

Is the atmosphere stable?

T = 15°C at 10m high  
T = 11°C at 350m high

$$\Gamma = \text{adiabatic lapse rate} \\ = \frac{-10^\circ\text{C}}{\text{km}} = \frac{-1^\circ\text{C}}{100\text{m}} \\ \text{equivalent values}$$

$$\frac{\Delta T}{\Delta z} = \frac{11 - 15}{350 - 10} = \frac{-4^\circ\text{C}}{340\text{m}} = -0.01176^\circ\text{C}/\text{m}$$

$$= -11.76^\circ\text{C}/\text{km}$$

OR

We need to compare this calculated value to the adiabatic lapse rate, so we need the same units

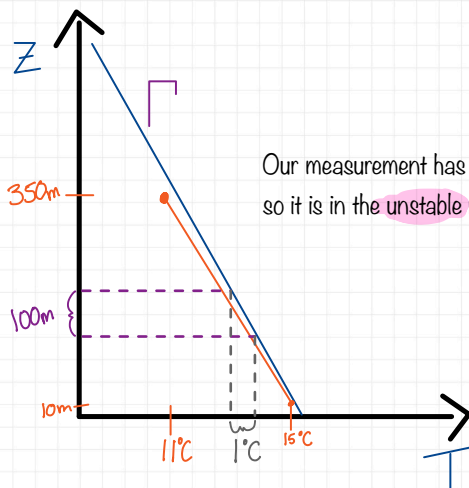
We'll use our handy, typical trick of multiplying by "one" but with a slight twist

$$-0.01176^\circ\text{C}/\text{m} \times \frac{100}{100} = \frac{-1.176^\circ\text{C}}{100\text{m}}$$

In the denominator, the 100 becomes part of the unit

$$-11.76^\circ\text{C}/\text{km} < -10^\circ\text{C}/\text{km}$$

$$-1.176^\circ\text{C}/100\text{m} < -1^\circ\text{C}/100\text{m}$$



Our measurement has a more negative slope  
so it is in the **unstable** region