PE1:13-15

An Orsat analysis determined a stack gas composed of 3.0 mole% carbon monoxide, 10.6 mole% carbon dioxide, 6.0 mole% oxygen, and 80.4 mole% nitrogen. Dry air enters the combustion chamber.

PE1:13

- The amount of carbon burned in most nearly:

Sol. PE1:13

Comp	Feed	Dry	Reaction	Wet	Wet Mol %
CO_2	0	10.6	10.6		9.95
CO	0	3.0	1.5		2.82
H_2O	0		O_2 used = 15.36-10.6-1.5= **3.26** mols	2(3.26) = **6.52** mol	6.12
N_2	80.4	80.4	0		75.5
O_2	80.4/ .764 =**21.36**	**6.0**	21.36-6.0=**15.36**		5.63
Total	101.76	100		100+6.52 = **106.52**	100

PE1:14

- The amount of air used (wet basis) is most nearly:

Sol. PE1:14

- Basis: 100 mols of wet stack

Nitrogen: 80.4 mol%

Dry Air provided: 80.4(4.764)/(3.764)= 101.76 mol

Wet air volume = 100+6.54 = 106.54 mol

Dry air = 101.76/106.54

- = 95.51 mols /100 mol of wet gas

PE1:15

- The excess air is most nearly:

Sol: PE1:15

Oxygen consumed for CO_2 = 10.6 moles

Oxygen consumed for CO = ½(3.0) = 1.5 moles

Oxygen consumed for H_2O= 3.26 mols

Oxygen in the stack as = 6.0 mol%

Total oxygen supplied = 10.6+1.5+3.27+6.0 = 21.37 moles

Theoretical Oxygen required = 10.6+3.0+3.27 = 16.87 moles

Mol % excess oxygen = (21.37-16.87)/16.87 =26.67%

Mol % air = 26.67%

PE1:16-19

Natural gas is burned in a furnace at a rate of 45.0 m^3/day. Fuel and air enter the furnace at 101.3 kPa and 25 C. Natural gas is composed mainly of methane but may include up to 10.0 mol% ethane, 3.0 mol% propane and 1.0 mol% butane, and 0.5 mol% pentane. The typical natural gas makeup is tabulated with the following combustion data. Heat capacity data are also provided.

PE1:16-19

Comp	Mol%	ΔH298, kJ/mol
Methane	94.4	-890.4
Ethane	3.4	-1560
Propane	0.6	-2220
Butane	0.5	-2874
Pentane	-	-3533
Carbon dioxide	0.6	-
nitrogen	0.5	-

	J/mol °C
$(c_p)_{CO_2}$	$36.80 + 1.406\times10^{-2}\ T$
$(c_p)_{H_2O}$	$33.43 + 8.392\times10^{-3}\ T$
$(c_p)_{O_2}$	$29.27 + 4.683\times10^{-3}\ T$
$(c_p)_{N_2}$	$28.99 + 2.729\times10^{-3}\ T$

PE1:16

- The natural gas is burned with 100% excess air. Determine the air-flow rate based on the typical flow rate based on the fuel consumption.

Sol PE1:16

Comp	Oxygen	CO2	Water	y	O2 Reqd.	CO2	H2O
CH_4	$2O_2$	CO_2	$2H_2O$	0.944	1.888	0.944	1.88
C_2H_6	$3.5O_2$	$2CO_2$	$3H_2O$	0.034	0.119	0.068	0.102
C_3H_8	$5O_2$	$3CO_2$	$4H_2O$	0.006	0.03	0.018	0.024
C_4H_{10}	$6.5O_2$	$4CO_2$	$5H_2O$	0.005	0.0325	0.020	0.025
1 mol of NG	2.070	1.112	2.031				

$$N = \frac{pV}{RT} = \frac{(101325)(45)}{(8.314)(298)} = 1840 \text{ mol/d};$$

	Feed	Rx	Prod
O_2		*-1.1255	Excess = 100% = 2.070
N_2	0.005	0	0.005 + 15.583 = 15.588
CO_2	0.006	1.112	1.118
H_2O	0	2.031	2.031
Air	4.14*4.764 = 19.723	*	

Total = 2.070 + 15.588+ 1.118 + 2.031 = 20.807

Air flow rate = 19.723(45)=887.54 m^3/d

PE1:17

- What is the typical flue gas molar composition assuming complete combustion?

Sol. PE1:17

	Prod	Comp
O_2	2.070	9.95
N_2	15.588	74.92
CO_2	1.118	5.37
H_2O	2.031	9.76
Air	20.807	100

PE1:18

- The walls of the furnace must be constructed of materials capable of withstanding the highest temperature produced in the furnace. Assuming a constant fuel-flow rate, calculate the highest theoretical temperature produced in the furnace?

Sol PE1:18

Comp	Oxygen	CO_2	Water	y	O_2 Reqd.	CO_2	H_2O
CH_4	$2O_2$	CO_2	$2H_2O$	0.855	1.71	0.855	1.71
C_2H_6	$3.5O_2$	$2CO_2$	$3H_2O$	0.10	0.35	0.2	0.3
C_3H_8	$5O_2$	$3CO_2$	$4H_2O$	0.03	0.15	0.09	0.12
C_4H_{10}	$6.5O_2$	$4CO_2$	$5H_2O$	0.01	0.065	0.04	0.05
C_5H_{12}	$8O_2$	$5O_2$	$6H_2O$	0.005	0.04	0.025	0.048
1 mol of NG	2.315	1.21	2.228				

Comp	y	ΔHc	yΔHc
CH_4	0.855	-890.4	-761.3
C_2H_6	0.10	-1560	-156
C_3H_8	0.03	-2220	-66.6
C_4H_{10}	0.01	-2874	-28.74
$C_5H_{12}A$	0.005	-3533	-17.66
1 mol of NG			-1030.3 kJ

Nitrogen = 79/21(2.315)=8.709

	Prod	a	b	na	nb
O_2		29.27	4.683×10^{-3}		
N_2	8.709	28.99	2.729×10^{-3}	252.47	2.38×10^{-2}
CO_2	1.21	36.80	1.406×10^{-2}	44.53	1.70×10^{-2}
H_2O	2.228	33.43	8.392×10^{-3}	74.48	1.87×10^{-2}
				371.48	5.95×10^{-2}

Moles of water produced = 2.28(2442)(18)=100220 J

Enthalpy of products = 1030300-100220 = 930080 J

$$\Delta H_f = \Delta H^o + aT_F + \frac{b}{2}T_F^2 = 0$$

$$\Delta H^o = -371.48(25) - \frac{5.95 \times 10^{-2}}{2}(25)^2 = -9306$$

$$\Delta H_p = \Delta H^o + aT_P + \frac{b}{2}T_P^2 = 930080$$

$$-9306 + 371.48T + 2.975 \times 10^{-2}T^2 = 930080$$

$$2.975 \times 10^{-2}T^2 + 371.48T - 939386 = 0$$

$$T = \frac{-371.48 + \sqrt{371.48^2 + 4(2.975 \times 10^{-2})(939386)}}{2(2.975 \times 10^{-2})} = 2156\ C$$

PE1:19

- The flue-gas rate that occurs under the conditions posed in PE1:18 is most nearly:

Sol. PE1:19

- Number of moles of Flue gas = 1.21 + 2.228+8.709 = 12.147
- Volumetric flow rate= $\frac{45(12.147)(2156+273)}{298} =$ $4455\,\frac{m3}{d}$