GJ

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ENCH 501: Transport Phenomena

Mid-Term Examination, Fall 2010

Instructions: Time: 2:00 to 3:30 pm Oct 19, 2010
Attempt All Questions. Open Notes & Book.
Use of calculators permitted

Problem #1 (15 points)

Many operations in the chemical and petroleum industries involve chemical reactions. These include upgrading of bitumen, production of synthetic oils and recovery of metals from ores.

An iron pyrite ore contains 85% by weight of FeS_2. The balance is an inert solid material called ***gangue***. The ore is roasted with air in a furnace to produce iron oxide. The amount of air supplied is 200% in excess of what is required theoretically to completely oxidize FeS_2 in feed ore.
The reaction's stoichiometric relationship is

$$4\,FeS_2 + 11\,O_2 = 2\,Fe_2O_3 + 8\,SO_2$$

Assume gangue does not react or vaporize in the furnace, and no reactions other than foregoing occurred in the furnace. The solid residue left after roasting (including all the iron oxide) is called ***cinder*** and it contained 2% by weight FeS_2.

a) Determine the mass fractions of the components of the cinder. Show your steps.
b) What are the mole fractions of the components of the gas from the furnace?

Data: The molar masses (kg/kmols) are: FeS_2 - 120; Fe_2O_3 - 160; SO_2 - 64; Air - 29.
Air contains 21 mole % oxygen and 79% nitrogen.

Problem #2 (10 points)

A health-care professional will often measure one's blood pressure to check health status with a sphygmomanometer. This is a device with a cuff that is attached to the arm and either an electronic readout or a stethoscope. The systolic pressure (peak pressure at the end of the cardiac cycle), diastolic pressure (at the end of the cycle) and the heart rate are determined. A healthy resting adult normally has a systolic pressure in the 90-120 mm Hg range, and a diastolic pressure of 60-80 mm Hg. In a test, 100 subjects with no known history of hypertension had an average blood pressure of 112/64 mm Hg.

Data recorded for an individual at the same time of the day, over several days, are presented in the table below. (The person has an unchanging daily routine.) These are stated to be resting data. Estimate the ***average values and the errors*** for each of the pressures and the heart rates if **(i)** the data were collected using different equipment and by different operators, and **(ii)** if the same operator collected the data on the same equipment.

Systolic pressure, mm Hg	*Diastolic pressure, mm Hg*	*Heart rates, per min*
137	88	66
121	86	59
111	90	61

108	72	59
126	76	71
108	78	64
120	75	68
135	84	72
189	124	84
110	74	66
122	82	62

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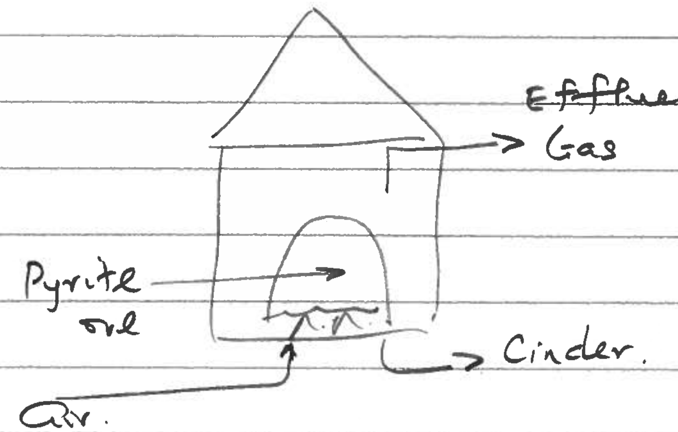
1)



Reaction:

$4FeS_2 + 11O_2 \rightarrow 2Fe_2O_3 + 8SO_2$

Choose basis: 100 kg ore

→ contains 85 kg FeS_2 + 15 kg gangue

Since molar mass FeS_2 = 120 kg/kmol, feed contains 0.7083 kmols FeS_2

Consider the air.

moles required of O_2 = $\frac{0.7083}{4} \cdot 11 = 1.9479$ kmols

Moles air required = $1.9479 / 0.21 = 9.2758$ kmol

∴ Total air feed = 3 × required = 27.8274 kmol

This includes 0.79 (27.8274) = 21.9836 kmols of N_2 that does not react.

The effluent gas will contain — N_2, O_2 and SO_2

The cinder will contain FeS_2 (unreacted), Fe_2O_3 and gangue.

(a) Let x kg FeS_2 remain in cinder.

~~Mass~~ FeS_2 burned $= 85 - x$ kg or $\frac{85-x}{120}$ kmols

Fe_2O_3 produced $= \frac{(85-x)\,2}{120\,(4)} = \frac{85-x}{240}$ kmols

or $\frac{85-x}{240}(160)$ kg $= \frac{2}{3}(85-x)$ kg

Wt. of cinder

$= 15 + \frac{2}{3}(85-x) + x$

(15 kg gangue, $\frac{2}{3}(85-x)$ kg Fe_2O_3, x kg FeS_2)

But, for FeS_2 in cinder

$x = 0.02\left(15 + \frac{2}{3}(85-x) + x\right)$

$50x = 15 + \frac{2}{3}(85) - \frac{2}{3}x + x$

$49.667\,x = 15 + \frac{2}{3}(85)$ $\Rightarrow x = 1.443$ kg FeS_2 unreacted

∴ Cinder		mass %
FeS_2	1.443 kg	2
Fe_2O_3	55.705 kg	77.21
gangue	15 kg	20.79
	72.148 kg	100 %

(b) For Gas from furnace →

— components are SO_2 (produced), O_2 (unburnt) + N_2 (inert)

Moles N_2 supplied − 21.98363 kmols — previous calc.

Moles O_2 supplied $= 3(1.9479) = 5.8437$ kmols

Moles O_2 used $= \frac{85-x}{120}\left(\frac{11}{4}\right) = 1.914848$ kmols
(from moles FeS_2 burned)

moles of SO_2 produce = $\frac{85-x}{120}\left(\frac{8}{4}\right)$ = 1.3926 kmols.
(from moles FeS_2 burned)

Gas from furnace.

		kmols.	mole fractions
N_2	–	21.98363	0.8051
excess O_2	–	5.8437 – 1.914848	
		= 3.9288	0.14388
SO_2	–	1.3926	0.05100
		27.305	0.9999 ≃ 1.0

⟶

#2

	Systolic	Δ	Diastolic	Δ	Heart Rate	Δ
	137	17.2	88	7.5	66	1.2
	121	1.2	86	5.5	59	-5.8
	111	-8.8	90	9.5	61	-3.8
	108	-11.8	72	-8.5	59	-5.8
	126	6.2	74	-4.5	71	6.2
	108	-11.8	78	-2.5	64	-0.8
	120	0.2	75	-5.5	68	3.2
	135	15.2	84	3.5	72	7.2
outlier	~~189~~		~~124~~		~~84~~	
	110	-9.8	74	-6.5	66	1.2
	122	2.2	82	1.5	62	-2.8
Av	1198/10 = 119.8 mm Hg		805/10 = 80.5 mm Hg		648/10 = 64.8	

← Mean values

⇒ On examination of the data, one set appears to be an outlier. This is dropped.

⇒ Calculate Δ values — $x_i - \bar{x}$ for each.

(a) Data independent. — error calculations

$$\Delta x = \sqrt{\sum_{i=1}^{N} \frac{(x_i - \bar{x})^2}{N-1}}$$

systolic $= \sqrt{\frac{1023.6}{9}} = 10.66$

diastolic $= \sqrt{362.5/9} = 6.35$

Heart Rate. $= \sqrt{193.6/9} = 4.64$

(b) Data Correlated — error calculation

$$Dx = \sum_{i=1}^{N} \left| \frac{x_i - \bar{x}}{N} \right|$$

Systolic $= \frac{84.4}{10} = 8.44$

diastolic $= 55/10 = 5.5$

Heart rate $= 38/10 = 3.8$

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