Appendix 5A

TG data for pyrolysis of coal

Time (min)	Temp. (^{O}C)	Temp. (K)	Coal from Bhilai Steel Plant			Coal from Jharia Mines		
			Wt. remaining(µg)	Wt. loss (µg)	Cumul. Wt. loss (µg)	Wt. remaining (µg)	Wt. loss (µg)	Cumul. Wt. loss (µg)
zero	20.0	293.0	7753.0	zero	zero	8231.0	zero	zero
1.23	26.9	299.9	7747.9	5.1	5.1	8228.4	2.6	2.6
4.78	56.0	329.0	7696.4	51.5	56.6	8201.6	26.8	29.4
6.87	80.5	353.5	7668.1	28.3	84.9	8186.9	14.7	44.1
8.79	105.2	378.2	7654.7	13.4	98.3	8179.9	7.0	51.1
10.62	129.8	402.8	7647.5	7.2	105.5	8176.1	3.8	54.9
12.40	154.4	427.4	7642.5	5.0	110.5	8173.5	2.6	57.5
14.13	179.0	452.0	7638.0	4.5	115.0	8171.2	2.3	59.8
15.98	205.8	478.8	7631.9	6.1	121.1	8168.0	3.2	63.0
17.67	230.8	503.4	7624.5	7.4	128.5	8164.2	3.8	66.8
19.34	255.1	528.1	7615.0	9.5	138.0	8159.3	4.9	71.7
21.02	279.7	552.7	7602.8	12.2	150.2	8152.9	6.4	78.1
22.09	295.4	568.4	7593.5	9.3	159.5	8148.0	4.9	83.0
23.76	319.9	592.9	7576.9	16.6	176.1	8139.4	8.6	91.6
25.45	344.6	617.6	7554.3	22.6	198.7	8127.7	11.7	103.3
27.13	369.2	642.2	7522.5	31.8	230.5	8111.2	16.5	119.8
28.98	396.0	669.0	7468.7	53.8	284.3	8083.2	28.0	147.8
30.66	420.6	693.6	7376.5	92.2	376.5	8035.3	47.9	195.7
32.37	445.2	718.2	7194.0	182.5	559.0	7940.5	94.8	290.5
34.10	469.9	742.6	6907.5	286.5	845.5	7791.6	148.9	439.4
35.84	494.4	767.4	6613.7	293.8	1139.3	7638.9	152.7	592.1
37.62	519.0	792.0	6394.8	218.9	1358.2	7525.1	113.8	705.9
39.56	545.9	818.9	6241.6	153.2	1511.4	7445.5	79.6	785.5
41.36	570.5	843.5	6142.9	98.7	1610.1	7394.2	51.3	836.8
43.16	595.1	868.1	6061.8	81.1	1691.2	7352.1	42.1	878.9
44.95	619.7	892.7	5991.2	70.6	1761.8	7315.4	36.7	915.6
46.79	644.4	917.4	5925.7	65.5	1827.3	7281.4	34.0	949.6
48.76	671.1	944.1	5861.3	64.4	1891.7	7247.9	33.5	983.1
50.57	695.8	968.8	5806.3	55.0	1946.7	7219.3	28.6	1011.7
52.39	720.4	993.4	5756.9	49.4	1996.1	7193.7	25.6	1037.3
54.20	745.0	1018.0	5712.8	44.1	2040.2	7170.8	22.9	1060.2
56.01	769.6	1042.6	5673.6	39.2	2079.4	7150.4	20.4	1080.6
57.87	794.3	1067.3	5638.6	35.0	2114.4	7132.2	18.2	1098.8
59.87	821.0	1094.0	5608.9	29.7	2144.1	7116.8	15.4	1114.2
62.03	842.6	1115.6	5588.7	20.2	2164.3	7106.6	10.2	1124.4
63.53	870.3	1143.3	5564.7	24.0	2188.3			
65.28	895.6	1168.6	5546.4	18.3	2206.6			

Appendix 5B

Calculation for fraction of volatiles released (f_{vr}) from composite pellet

The fraction of volatile released for ACP1 composite pellet is calculated as follows:

Source of coal used: Jharia mines

Volatile matter (VM) in coal = 15.65 %, Moisture in coal = 0.35 % ....(From Table 4.5)

For TG analysis of coal:

Amount of coal sample taken for TG analysis = 8231 μg

Total amount of VM present in coal (VM_{coal}) = 8231 x (15.65/100) = 1288.15 μg

Amount of moisture present in coal = 8231 x (0.35/100) = 28.80 μg

Amount of sample (composite pellet powder) taken for TG analysis = 8813 μg

Percent of coal present in composite pellet (C_1) = 32.49 % ....(From Table 4.8)

Amount of VM present in composite pellet (VM_{cp}) = 8813 x (32.49/100) x (15.65/100)

= 448.11 μg

Factor of proportionality (f_P) is calculated as:

$$f_P = \frac{\text{Amount of VM present in composite pellet sample}}{\text{Amount of VM present in coal sample used for pyrolysis}}$$

= (448.11 / 1288.15) = 0.3479

Now, from the Table given in Appendix 5A and the above data the values for fraction of volatiles released from composite pellet during TG analysis at a particular temperature are calculated and is shown in Table below.

Temp. (K)	Cumulative weight loss of coal during TG (μg), A	VM released from coal (μg), B = (A - moisture)	VM released from comp. pellet (μg), C = B x f_P	Fraction of VM released from comp. pellet, f_{vr} = (C / VM_{cp})
300.9	2.60	Nil	Nil	Nil
429.6	57.70	28.90	10.05	0.0224
601.5	95.63	66.83	23.25	0.052
811.0	762.12	733.32	255.12	0.569
1052.6	1087.97	1059.17	368.49	0.822
1232.4	1288.15 (Full VM)	1288.15	448.11	1.0
1361.3	1288.15 (Full VM)	1288.15	448.11	1.0

Appendix 5C

Calculation for degree of reduction

The degree of reduction for composite pellet ACP-1 is calculated as follows:

According to Eq. (3.81):

$$\alpha = \frac{400}{7} \times \left[\frac{f_{wl} - (f_{coal} \times f_{vm} \times f_{vr})}{(f_{ore} \times \rho_{ore} \times f_o)} \right]$$

Here, $f_{wl} = 0.2985$, $f_{coal} = 0.3249$, $f_{vm} = 0.1565$, $f_{vr} = 1.0$, $f_{ore} = 0.5870$, $\rho_{ore} = 0.956$, and $f_o = 0.30$. The sources of these data are Tables 4.3, 4.5, 4.8, 5.3 and 5.4.

$$\alpha = \frac{4}{7} \times \left(\frac{0.2985 - (0.3249 \times 0.1565 \times 1)}{0.5870 \times 0.956 \times 0.30} \right) \times 100$$

$$= \frac{4}{7} \times \left(\frac{0.2985 - 0.0508}{0.1684} \right) \times 100 = 84.06\,\%$$

Appendix 5D

Calculation for degree of reduction of composite pellet

The degree of reduction for composite pellet ACP-1 is calculated as follows:
For ACP1 pellet: m = 8813 μg, $f_{coal} = 0.3249$, $f_{vm} = 0.1565$, $f_{ore} = 0.5870$, $\rho_{ore} = 0.956$, and $f_o = 0.30$. The sources of these data are Tables 4.3, 4.5, 4.8, 5.3 and 5.4.

According to Eq. (3.76):

$$\alpha = \frac{4}{7m_o}[\Delta m_t - (m \times f_v)] \times 100$$

At temperature 811 K, Δmt = 707.6 μg

$$\alpha = \frac{4}{7} \times \left[\frac{\Delta m_t - (m \times f_v)}{m_o}\right] \times 100$$

$$= \frac{4}{7} \times \left[\frac{707.6 - (8813 \times 0.3249 \times 0.1565)}{8813 \times 0.5870 \times 0.956 \times 0.30}\right] \times 100$$

$$= \frac{4}{7} \times \left[\frac{707.6 - 448.11}{1483.68}\right] \times 100 = 9.99\%$$

According to Eq. (3.81):

$$\alpha = \frac{400}{7} \times \left[\frac{f_{wl} - (f_{coal} \times f_{vm} \times f_{vr})}{(f_{ore} \times \rho_{ore} \times f_o)}\right]$$

At temperature 811 K, $f_{wl} = 0.0803$ and $f_{vr} = 0.569$

$$\alpha = \frac{4}{7} \times \left(\frac{0.0803 - (0.3249 \times 0.1565 \times 0.569)}{0.5870 \times 0.956 \times 0.30}\right) \times 100$$

$$= \frac{4}{7} \times \left(\frac{0.0803 - 0.0289}{0.1684}\right) \times 100 = 17.44\%$$

Similar calculation can be done for ACP1 pellet at temperatures of 1052.6, 1232.4 and 1361.3 K. Similarly, according to Eqs. (3.76) and (3.81), the degree of reduction can be calculated at above temperatures for BCP1 pellets.

Appendix 5E

Activation energies for composite pellets reduction

T (^{0}C)	T (K)	1/T x 10^4 (K^{-1})	Rate of Reduction (k x 10^5) (s^{-1})	ln(k)	Activation Energy (kJ/mol)
ACP-1 Pellet					
27.9	300.9	33.2	2.82	-10.48	
156.7	429.6	23.3	4.26	-10.06	
328.5	601.5	16.6	4.53	-10.00	2.31
538.0	811.0	12.3	5.04	-9.90	
779.6	1052.6	9.50	6.74	-9.61	
959.4	1232.4	8.11	8.50	-9.37	14.44
1088.3	1361.3	7.35	11.90	-9.04	
ACP-2 Pellet					
27.9	300.6	33.2	2.97	-10.42	
156.8	429.8	23.3	2.93	-10.34	
358.1	631.1	15.9	3.60	-10.31	0.86
575.5	848.5	11.8	3.34	-10.23	
736.6	1009.6	9.90	6.46	-9.65	
954.0	1227.0	8.15	8.75	-9.34	21.53
1085.6	1358.6	7.36	11.37	-9.08	
ACP-3 Pellet					
28.6	301.6	33.2	0.43	-12.36	
140.6	413.6	24.2	1.16	-11.36	
331.2	604.2	16.6	2.61	-10.55	
438.6	711.6	14.1	3.31	-10.32	8.82
586.3	859.3	11.6	3.25	-10.23	
699.0	972.0	10.3	4.85	-9.93	
927.0	1200.0	8.33	6.99	-9.57	
1031.9	1304.9	7.66	9.73	-9.24	22.06
1085.6	1358.6	7.36	10.63	-9.15	
ACP-4 Pellet					
27.9	300.9	33.2	0.98	-11.53	
140.6	413.6	24.2	1.63	-11.02	
299.0	572.0	17.5	2.81	-10.48	
341.9	614.9	16.3	2.79	-10.39	5.59
427.0	700.0	14.3	3.41	-10.29	
589.0	862.0	11.6	3.82	-10.17	
728.5	1001.5	10.0	4.70	-9.97	
938.5	1211.5	8.26	6.16	-9.69	
1034.6	1307.6	7.65	8.41	-9.38	21.42
1085.6	1358.6	7.36	9.19	-9.29	

BCP-1 Pellet					
27.1	300.1	33.3	1.31	-11.24	
164.9	437.9	22.8	2.86	-10.46	
349.5	622.5	16.1	3.42	-10.23	4.55
561.1	834.1	12.0	3.60	-10.21	
772.7	1045.7	9.56	4.82	-9.94	
964.7	1237.7	8.08	8.00	-9.43	35.36
1087.6	1360.6	7.35	12.30	-9.00	
BCP-2 Pellet					
27.9	300.9	33.2	1.00	-11.51	
162.1	435.1	23.0	2.37	-10.65	
317.8	590.8	16.9	2.94	-10.43	4.98
548.7	821.7	12.2	4.05	-10.11	
763.5	1036.5	9.65	4.10	-10.10	
954.0	1227.0	8.15	7.58	-9.49	38.32
1088.3	1361.3	7.35	11.83	-9.04	
BCP-3 Pellet					
27.9	300.9	33.2	2.54	-10.58	
170.2	443.2	22.6	2.66	-10.53	1.15
358.1	631.1	15.8	3.23	-10.34	
527.2	800.2	12.5	5.98	-9.93	
723.2	996.2	10.0	4.87	-9.73	12.37
948.7	1221.7	8.20	7.76	-9.46	
1085.6	1358.6	7.40	11.31	-9.09	
BCP-4 Pellet					
27.9	300.9	33.2	0.92	-11.60	
170.2	456.6	21.9	2.36	-10.65	
358.1	609.6	16.4	3.36	-10.33	5.22
527.2	802.9	12.5	3.25	-10.30	
723.2	1004.2	9.96	4.84	-9.94	
948.7	1221.7	8.19	7.50	-9.50	18.69
1085.6	1358.6	7.34	10.70	-9.14	

Appendix 6A:

Calculation for degree of reduction

The degree of reduction for composite pellet ACP-1 is calculated as follows:
According to Eq. (3.81):

$$\alpha = \frac{400}{7} \times \left[\frac{f_{wl} - (f_{coal} \times f_{vm} \times f_{vr})}{(f_{ore} \times \rho_{ore} \times f_{o})} \right]$$

For composite pellet immersed in liquid metal bath for 10 seconds $f_{wl} = 0.088$, $f_{coal} = 0.3249$, $f_{vm} = 0.1565$, $f_{vr} = 1.0$, $f_{ore} = 0.5870$, $\rho_{ore} = 0.956$, and $f_o = 0.30$. The sources of these data are Table 4.3, 4.5, 4.8 and 6.1.

$$\begin{aligned} \alpha &= \frac{4}{7} \times \left(\frac{0.088 - (0.3249 \times 0.1565 \times 1)}{0.5870 \times 0.956 \times 0.30} \right) \times 100 \\ &= \frac{4}{7} \times \left(\frac{0.088 - 0.0508}{0.1684} \right) \times 100 \ = \ 12.62\,\% \end{aligned}$$

Appendix 6B

Volatile matters in composite pellets

The amount of volatile matters present in composite pellet was calculated as follows:
Amount of volatile matters (VM) in composite pellet = W_i x f_{coal} x f_{vm}

Where, W_i = Initial weight of pellet, f_{coal} = fraction of coal present in composite pellet, and f_{vm} = fraction of volatile matters present in coal

Pellet Code	Fe_{tot}/C_{fix} Ratio	Time of Immers-ion (s)	Initial Wt. of Pellet, W_i (g)	Final Wt. of Pellet, W_f (g)	Difference in Weight, W_r (g)	Amount of VM in pellet (g)
ACP-1	2.50	10	5.4912	5.0080	0.4832	0.2792
		20	5.6786	4.7730	0.9056	0.2887
		30	5.6766	4.2929	1.3837	0.2886
		40	6.2677	4.3378	2.9299	0.3187
ACP-2	3.11	10	8.0324	7.3773	0.6551	0.3506
		20	9.1013	7.7120	1.3893	0.3973
		30	8.3539	6.3670	1.9864	0.3646
		40	6.9078	4.7966	2.1112	0.3015
ACP-3	3.50	10	6.7635	6.2366	0.5269	0.2708
		20	6.3240	5.3661	0.9579	0.2532
		30	6.1091	4.7242	1.3849	0.2446
		40	6.7826	4.8229	1.9597	0.2715
ACP-4	4.00	10	5.8016	5.3705	0.4311	0.2099
		20	7.0851	6.1862	0.8989	0.2563
		30	5.8723	4.6607	1.2116	0.2125
		40	5.6480	4.1454	1.5026	0.2044
BCP-1	2.50	10	4.6463	4.0630	0.5833	0.3637
		20	5.5113	4.3981	1.1132	0.4314
		30	6.5288	4.6235	1.9035	0.5110
		40	6.6292	4.2233	2.4059	0.5189
		50	6.3437	3.9207	2.4230	0.4965
BCP-2	3.11	10	5.9002	5.2100	0.6902	0.3936
		20	6.0034	4.8416	1.1618	0.4005
		30	6.9066	5.0198	1.8868	0.4608
		40	6.2336	4.0505	2.1831	0.4159
BCP-3	3.50	10	6.1449	5.4863	0.6586	0.3746
		20	6.0653	4.9742	1.0911	0.3698
		30	5.7407	4.2272	1.5135	0.3500
		40	5.7971	3.8948	1.9023	0.3534
		50	5.7867	3.7844	2.0023	0.3528
BCP-4	4.00	10	7.0719	6.4134	0.6659	03882
		20	7.2245	6.0167	1.2078	0.3960
		30	6.5681	4.9952	1.5729	0.3605
		40	6.1359	4.2276	1.9083	0.3368
		50	6.1448	4.0931	2.0517	0.3373

Appendix 6C

Calculation for iron yield

For Heat H1 (ACP1 pellet, Fe_{tot}/C_{fix} ratio = 2.50):

Weight of cast iron scrap charged, $W_1 = 3000$ g

Weight of composite (ACP1) pellet charged, $W_2 = 1000$ g

Weight of initial sample collected for analysis = 178 g

Weight of cast metal = 3124 g

Weight of hot metal produced, $W_3 = (3124 + 178)$ g = 3302 g

Fe input:

Percent Fe content in initial sample, $I_1 = (100 - 3.154)\ \% = 96.846\ \%$

Fe that comes from cast iron scrap charged $= W_1 \times I_1$

$= 3000 \times (96.846/100) = 2905.38$ g

Fe that comes from composite pellet charged $= W_2 \times F_1 \times F_{10}$

$= 1000 \times (58.70/100) \times (66.90/100)$

$= 392.70$ g

Total Fe in input = (2905.38 + 392.70) g = 3298.08 g

Fe output:

Percent Fe content in product metal, $I_2 = (100 - 3.173)\ \% = 96.827\ \%$

Total Fe in product metal $= W_3 \times I_2$

$= 3302 \times (96.827/100) = 3197.23$ g

Fe recovery:

Percent Fe recovery = (Fe output / Fe input) x 100

= (3197.23 / 3298.08) x 100 = 96.94 %

Appendix 6D

Mass balance for smelting of composite pellets in an induction furnace

For Heat H1 (ACP1 pellet, Fe_{tot}/C_{fix} ratio = 2.50):

Iron ore analysis (source: Noamundi mines, Tata Steel, Jamshedpur, Jharkhand)

Fe = 66.90 % (≈ 95.57 % Fe_2O_3), SiO_2 = 1.09 %, Al_2O_3 = 1.41 %,

P_2O_5 = 0.16 %, Other oxides = 1.77 % (balance)

Proximate analysis of coal (source: Jharia mines, Dhanbad, Jharkhand)

Fixed carbon = 48.35 %, Ash = 35.65 %

Volatile matter = 15.65 %, Moisture = 0.35 %

Coal ash analysis

SiO_2 = 55.18 %, MgO = 0.15 %

Al_2O_3 = 24.57 %, SO_3 = 2.18 %

Fe_2O_3 = 17.19 %, CaO = 0.73 %,

Lime analysis

CaO = 99.85 %, ZrO_2 = 0.01 %, SrO = 0.14 %

Assumptions:

i) Removal of sulphur is in the form of CaS only

ii) 90 pct of carbon consumed forms CO gas and remaining 10 pct forms CO_2 gas

iii) No other elements (including iron) are oxidized during melting of cast iron scrap

Chemical composition:

Heat No.	Chemical composition (pct)								
	C	Mn	Cr	Ni	Si	Mo	S	P	Cu
H1(initial) cast iron scrap	1.79	0.09	0.21	0.19	0.27	0.04	0.114	0.27	0.18
H1 (final) product metal	1.95	0.03	0.19	0.19	0.20	0.04	0.113	0.30	0.16

Weight of cast iron scrap charged, W_1 = 3000 g

Weight of composite (ACP1) pellet charged, W_2 = 1000 g

Weight of hot metal produced, W_3 = 3302 g

Mass balance calculation is done according to the equations developed in Section 3.3.

Composite pellet composition (for Fe_{tot}/C_{fix} ratio = 2.5)

According to Eq. (3.54):

$$W_{coal} = \frac{W_0 \times F_{10}}{r \times F_9} = \frac{1000 \times 66.9}{2.5 \times 48.35} = 553.46\ g$$

The proportion of constituents in composite pellets is:

W_0 (weight of iron ore) = 1000 g (58.70 %)

W_{coal} (weight of coal) = 553.46 g (32.49 %)

Weight of lime @10 % of iron ore = 100 g (5.87 %)

Weight of dextrose @ 5% of iron ore = 50 g (2.94 %)

Total weight: 1703.46 g 100 %

Therefore, composition of composite pellet:

iron ore = 58.70 %, coal = 32.49 %, slaked lime = 5.87 %, dextrose = 2.94 %

Fe balance

Fe input:

Percent Fe content in initial sample, I_1 = (100 – 3.154) % = 96.846 %

Fe that comes from cast iron scrap charged = W_1 x I_1

= 3000 x (96.846/100) = 2905.38 g

Fe that comes from composite pellet charged = W_2 x F_1 x F_{10}

= 1000 x (58.70/100) x (66.90/100)

= 392.70 g

Total Fe in input = (2905.38 + 392.70) g = 3298.08 g

Fe output:

Percent Fe content in product metal, I_2 = (100 – 3.173) % = 96.827 %

Total Fe in product metal = W_3 x I_2

= 3302 x (96.827/100) = 3197.23 g

Hence, Fe loss in slag w.r.t. total Fe input (W_4):

W_4 = Total Fe in input – Total Fe in output

= (3298.08 - 3197.23) g = 100.85 g

Percent Fe loss in slag = (Fe loss in slag / Total Fe in input) x 100

= (100.85 / 3298.08) x 100 = 3.06 %

Weight of FeO goes to slag (W_5):

$W_5 = (72 / 56) \text{ x } W_4$ ....From Eq. (3.8)

$= (72 / 56) \text{ x } 100.85 = 129.66 \text{ g}$

SiO_2 balance

$$W_6 = \frac{60}{28\times 10^2}\left[(W_1\times I_3)-(W_3\times I_4)\right]+\frac{W_2}{10^4}\left(F_1\times F_5+L_1\times L_2+\frac{C_1\times A_1\times A_2}{100}\right) \text{....}From\,Eq.(3.12)$$

$$= \frac{60}{28\times 10^2}\left[(3000\times 0.27)-(3302\times 0.20)\right]+$$

$$\frac{1000}{10^4}\left((58.70\times 1.09)+(5.87\times 0)+\frac{(32.49\times 35.65\times 55.18)}{100}\right)$$

$$= 17.36-14.15+6.40+63.91=73.52\ g$$

MnO balance

$$W_7 = \frac{71}{55\times 100}(W_1\times I_5 - W_3\times I_6)+\frac{W_2}{10^4}\left(F_1\times F_6+\frac{C_1\times A_1\times A_3}{100}\right) \text{........}From\,Eq.(3.16)$$

$$= \frac{71}{55\times 100}(3000\times 0.09-3302\times 0.03)+\frac{1000}{10^4}\left((58.70\times 0)+\frac{32.49\times 35.65\times 0.15}{100}\right)$$

$$= 3.49-1.28+0.17=2.38\ g$$

P_2O_5 balance

$$W_8 = \frac{142}{62\times 100}(W_1\times I_7 - W_3\times I_8)+\frac{W_2}{10^4}\left(F_1\times F_7+\frac{C_1\times A_1\times A_4}{100}\right) \text{.........}From\,Eq.(3.20)$$

$$= \frac{142}{62\times 100}(3000\times 0.27-3302\times 0.30)+\frac{1000}{10^4}\left((58.7\times 0.16)+\frac{32.49\times 35.65\times 0}{100}\right)$$

$$= 18.55-22.69+1.37=-2.77\ g$$

MgO balance

$$W_{11} = \frac{W_2}{10^4}\times\left(\frac{C_1\times A_1\times A_7}{100}+L_1\times L_5\right) \text{............}From\,Eq.(3.28)$$

$$= \frac{1000}{10^4}\times\left(\frac{32.49\times 35.65\times 0.0}{100}+5.87\times 0.0\right)= 0.0\ g$$

Carbon balance

$$W_C = \frac{1}{100}\left(\frac{(W_2\times C_1\times F_9)}{100}+(W_1\times I_9)-\ (W_3\times I_{10})\right) \text{..........}From\,Eq.\ (3.30)$$

$$= \frac{1}{100}\left(\frac{(1000\times 32.49\times 48.35)}{100}+(3000\times 1.79)-(3302\times 1.95)\right)$$

$$= \frac{1}{100}(15709+5370-6439)=146.40\,g$$

Now, amount of CO gas formed after reduction of iron oxide present in composite pellets

$$W_{12} = \frac{28}{12} \times W_C \times 0.90 \qquad \text{.........}\textit{From Eq.}\,(3.31)$$

$$= \frac{28}{12} \times 146.40 \times 0.90 = 307.44\ g$$

and amount of CO_2 gas formed

$$W_{13} = \frac{44}{12} \times W_C \times 0.10 \qquad \text{..........}\textit{From Eq.}\,(3.33)$$

$$= \frac{44}{12} \times 146.40 \times 0.10 = 53.68\ g$$

Sulphur balance

$$W_{14} = \frac{1}{10^2}(W_1 \times I_{11} - W_3 \times I_{12}) + \frac{W_2}{10^6}(C_1 \times A_1 \times A_8) \qquad \text{..........}\textit{From Eq.}\,(3.39)$$

$$= \frac{1}{10^2}(3000 \times 0.114 - 3302 \times 0.113) + \frac{1000}{10^6}\left(\frac{32.49 \times 35.65 \times 32}{80}\right)$$

$$= 3.42 - 3.730.0 + 1.01 = 0.70\ g$$

Now, amount of CaS formed due to reaction of sulphur with CaO (W_{15}):

$$W_{15} = \frac{72}{32} \times W_{14} \qquad \text{.............}\textit{From Eq.}\,(3.40)$$

$$= \frac{72}{32} \times 0.70 = 1.58\ g$$

Amount of CaO converted into CaS (W_{16}):

$$W_{16} = \frac{56}{72} \times W_{15} \qquad \text{............}\textit{From Eq.}\,(3.41)$$

$$= \frac{56}{72} \times 1.58 = 1.23\ g$$

CaO balance

$$W_9 = \frac{W_2}{10^4}\left((L_1 \times L_3) + \frac{(C_1 \times A_1 \times A_5)}{100}\right) - W_{16} \qquad \text{............}\textit{From Eq.}(3.24)$$

$$= \frac{1000}{10^4}\left((5.87 \times 99.85) + \frac{(32.49 \times 35.65 \times 0.73)}{100}\right) - (1.23)$$

$$= 58.61 + 0.85 - 1.23 = 58.23\ g$$

Al_2O_3 balance

$$W_{10} = \frac{W_2}{10^4}\left(F_1 \times F_8 + \frac{C_1 \times A_1 \times A_6}{100} + L_1 \times L_4\right) \qquad \text{..........}\mathit{From\,Eq.}(3.26)$$

$$= \frac{1000}{10^4}\left((58.70 \times 1.41) + \frac{(32.49 \times 35.65 \times 24.57)}{100} + (5.87 \times 0)\right)$$

$$= 8.28 + 28.46 = 36.74\ g$$

Oxygen balance

Weight of oxygen required for oxidation of iron going into slag (O_1):

$$O_1 = \frac{16}{72} \times W_5 = \frac{16}{72} \times 129.66 = 28.81\ g \qquad \text{.........}\mathit{From\,Eq.}(3.10)$$

Weight of oxygen required for oxidation of silicon (O_2):

$$O_2 = \frac{32}{28 \times 10^2}\,(W_1 \times I_3 - W_3 \times I_4) \qquad \text{..........}\mathit{From\,Eq.}(3.14)$$

$$= \frac{32}{28 \times 10^2}\,(3000 \times 0.27 - 3302 \times 0.20) = 1.71\ g$$

Weight of oxygen required for oxidation of manganese (O_3):

$$O_3 = \frac{16}{55 \times 10^2} \times (W_1 \times I_5 - W_3 \times I_6) \qquad \text{..........}\mathit{From\ Eq.}(3.18)$$

$$= \frac{16}{55 \times 10^2} \times (3000 \times 0.09 - 3302 \times 0.03) = 0.50\ g$$

Weight of oxygen required for oxidation of phosphorous (O_4):

$$O_4 = \frac{80}{62 \times 10^2} \times \left(W_1 \times I_7 - W_3 \times I_8\right) \qquad \text{............}\mathit{From\,Eq.}(3.22)$$

$$= \frac{80}{62 \times 10^2} \times \left(3000 \times 0.27 - 3302 \times 0.30\right) = -2.33\ g$$

Weight of oxygen required for CO gas formation (O_5):

$$O_5 = \frac{16}{12} \times W_C \times 0.90 \qquad \text{............}\mathit{From\,Eq.}\ (3.32)$$

$$= \frac{16}{12} \times 146.4 \times 0.90 = 175.68\ g$$

Weight of oxygen required for CO_2 gas formation (O_6):

$$O_6 = \frac{32}{12} \times W_C \times 0.10 \qquad ....From\,Eq.\,(3.34)$$

$$= \frac{32}{12} \times 146.4 \times 0.10 = 39.04\ g$$

Oxygen coming from iron ore present in composite pellets (O_7):

$$O_7 = \left(\frac{W_2 \times F_1 \times F_2}{100 \times 100}\right) \times \frac{48}{160} \qquad ....From\,Eq.\,(3.36)$$

$$= \left(\frac{1000 \times 58.70 \times 95.57}{100 \times 100}\right) \times \frac{48}{160} = 168.30\ g$$

Weight of oxygen required for oxidation of chromium (O_9):

$2Cr + 3/2\ O_2 = Cr_2O_3$

(104) (48) (152)

$$O_9 = \frac{48}{104} \times \left(\frac{W_1 \times I_{13}}{100} - \frac{W_3 \times I_{14}}{100}\right)$$

$$= \frac{48}{104} \times \left(\frac{3000 \times 0.21}{100} - \frac{3302 \times 0.19}{100}\right) = 0.014\ g$$

Weight of oxygen required for oxidation of copper (O_{10}):

$2Cu + ½\ O_2 = Cu_2O$

(127) (16) (143)

$$O_{10} = \frac{16}{127} \times \left(\frac{W_1 \times I_{15}}{100} - \frac{W_3 \times I_{16}}{100}\right)$$

$$= \frac{16}{127} \times \left(\frac{3000 \times 0.18}{100} - \frac{3302 \times 0.16}{100}\right) = 0.015\ g$$

Hence, oxygen required from atmosphere:

$$O_8 = \left[\ \{(O_1 + O_2 + O_3 + O_4 + O_5 + O_6 + O_9 + O_{10})\} - O_7\right] \quad ....From\,Eq.(3.37)$$

$$= \left[\{28.81 + 1.71 + 0.50 + (-2.33) + 175.68 + 39.04 + 0.014 + 0.015\} - (168.30)\right]$$

$$= 245.769 - 170.63 = 75.139\ g$$

Amount of other oxides except SiO_2, MnO, FeO, Al_2O_3 and P_2O_5 coming from iron ore present in composite pellets (W_{17}):

$$W_{17} = \left(\frac{W_2 \times F_1 \times F_{11}}{100 \times 100}\right) \qquad \text{.............} \textit{From Eq.} (3.42)$$

$$= \left(\frac{1000 \times 58.70 \times 1.77}{100 \times 100}\right) = 10.39 \ g$$

Amount of FeO (W_{18}) that goes to slag due to the presence of Fe_2O_3 in coal-ash:

$Fe_2O_3 + Fe = 3\ FeO$ ....From Eq. (3j)

(160) (56) (216)

$$W_{18} = \frac{216}{160} \times \left(\frac{W_2 \times C_1 \times A_1 \times A_9}{100 \times 100 \times 100}\right) \qquad \text{............} \textit{From Eq.} (3.43)$$

$$= \frac{216}{160} \times \left(\frac{1000 \times 32.49 \times 35.65 \times 17.19}{100 \times 100 \times 100}\right) = 26.88 \ g$$

Amount of dextrose present in composite pellets (W_{19}):

$$W_{19} = \left(\frac{W_2 \times F_{12}}{100}\right) \qquad \text{...........} \textit{From Eq.} (3.44)$$

$$= \left(\frac{1000 \times 2.94}{100}\right) = 29.40 \ g$$

Volatile matters (VM) present in coal of composite pellets (W_{20}):

$$W_{20} = \left(\frac{W_2 \times C_1 \times F_{13}}{100 \times 100}\right) \qquad \text{...........} \textit{From Eq.} (3.45)$$

$$= \left(\frac{1000 \times 32.49 \times 15.65}{100 \times 100}\right) = 50.85 \ g$$

Moisture present in coal of composite pellets (W_{21}):

$$W_{21} = \left(\frac{W_2 \times C_1 \times F_{14}}{100 \times 100}\right) \qquad \text{............} \textit{From Eq.} (3.46)$$

$$= \left(\frac{1000 \times 32.49 \times 0.35}{100 \times 100}\right) = 1.14 \ g$$

Amount of Cr_2O_3 that goes to slag (W_{23}):

$$W_{23} = \frac{152}{104} \times \left(\frac{W_1 \times I_{13}}{100} - \frac{W_3 \times I_{14}}{100} \right)$$

$$= \frac{152}{104} \times \left(\frac{3000 \times 0.21}{100} - \frac{3302 \times 0.19}{100} \right) = 0.044\ g$$

Amount of Cu_2O that goes to slag (W_{24}):

$$W_{24} = \frac{143}{127} \times \left(\frac{W_1 \times I_{15}}{100} - \frac{W_3 \times I_{16}}{100} \right)$$

$$= \frac{143}{127} \times \left(\frac{3000 \times 0.18}{100} - \frac{3302 \times 0.16}{100} \right) = 0.14\ g$$

Weight of slag produced (W_{22}):

$W_{22} = (W_5 + W_6 + W_7 + W_8 + W_9 + W_{10} + W_{11} + W_{15} + W_{17} + W_{18} + W_{23} + W_{24})$

..........*From Eq.*(3.47)

$= (129.66 + 73.52 + 2.38 + (-2.77) + 58.23 + 36.74 + 0.0 + 1.58 + 10.39 + 26.88$
$+ 0.044 + 0.14)$

$= 336.794\ g$

Based on the calculations done above, a summary of the mass balance for smelting of composite pellet in an induction furnace is given below.

Mass balance for smelting of composite pellet in an induction furnace

Input	Weight (g)	Output	Weight (g)
Cast iron scrap (W_1)	3000	Hot metal (W_3)	3302
Composite pellets (W_2)	1000	CO gas (W_{12}) and CO2 gas (W_{13})	307.44 53.68
Oxygen required from atmosphere (O_8)	75.14	Dextrose escaped as gases (W_{19})	29.40
		VM present in coal (W_{20})	50.85
		Moisture present in coal (W_{21})	1.14
		Slag (W_{22})	336.79
Total Input	4075.14	Total Output	4081.30