higher education & training

Department:
Higher Education and Training
REPUBLIC OF SOUTH AFRICA

NATIONAL CERTIFICATE

CHEMICAL PLANT OPERATION N5

(8050015)

24 November 2022 (X-paper)
09:00–12:00

Drawing instruments and nonprogrammable calculators may be used.

This question paper consists of 5 pages, 1 periodic table, 1steam table and 2 information sheets.

191Q1E2224

DEPARTMENT OF HIGHER EDUCATION AND TRAINING
REPUBLIC OF SOUTH AFRICA

NATIONAL CERTIFICATE
CHEMICAL PLANT OPERATION N5
TIME: 3 HOURS
MARKS: 100

INSTRUCTIONS AND INFORMATION

1. Answer all the questions.
2. Read all the questions carefully.
3. Number the answers according to the numbering system used in this question paper.
4. Start each question on a new page.
5. Use only a black or blue pen.
6. Write neatly and legibly.

QUESTION 1

Give ONE word/term for each of the following descriptions. Write only the word/term next to the question number (1.1–1.5) in the ANSWER BOOK.

1.1 Energy possessed because of movement (velocity) of matter.

1.2 A turbine in which the energy is received from an external source.

1.3 A material of necessity inert or unreactive which passes through a system from a single input stream to a single output stream and remains completely unchanged during the process.

1.4 The reaction from SO_2 to SO_3.

1.5 A mixer for light powders such as insecticides.

(5 × 1) **[5]**

QUESTION 2

Choose a/an word/item from COLUMN B that matches a description in COLUMN A. Write only the letter (A–H) next to the question number (2.1–2.5) in the ANSWER BOOK.

COLUMN A		COLUMN B	
2.1	Energy due to motion	A	heat
2.2	Mixer for heavy, stiff or gummy materials	B	fishtail blade
2.3	It is also called a double naben blade	C	oxygen
2.4	Can be used in food processing industries	D	nitrogen
2.5	It is colourless, odourless and tasteless gas with 79% of air by volume	E	hydrochloric acid
		F	potential energy
		G	bunbury mixer
		H	ribbon mixer

(5 × 1) **[5]**

QUESTION 3

3.1 Define the following:

3.1.1 Standard heat of formation

3.1.2 The gram mole

3.1.3 Combustion reaction

(3 × 3) (9)

3.2 Name TWO types of steam turbines. (2)

3.3 The analysis of the waste gas from a burner fuelled with natural gas (essentially pure CH_4) is as follows:

N_2 75 mol%; O_2 10 mol%; CO_2 5 mol% and H_2O 10 mol%.

What is the ratio of moles of air to moles of gas fed to the burner? (9)

[20]

QUESTION 4

4.1 Sketch a closed gas turbine and discuss it under the following headings. (7)

4.1.1 Advantage (1)

4.1.2 Disadvantages (2)

4.2 Write brief explanatory notes on an impulse-reaction turbine. (4)

4.3 Give FIVE procedures of solving material balance. (5 × 1) (5)

4.4 Describe a burner burning with a blue flame. (1)

[20]

QUESTION 5

5.1 5.1.1 Sketch a nozzle-discharge centrifuge. (7)

5.1.2 Explain the operation in QUESTION 5.1.1. (5)

5.2 Describe the operation of the following:

5.2.1 Two-arm kneader (5)

5.2.2 Centrifugal decanters (5)

5.3 Name THREE types of blades used in two-arm kneader. (3)

[25]

QUESTION 6

6.1 Draw a flowchart of the salt process for manufacturing of hydrochloric acid and give a description of the process. (15)

6.2 State THREE raw materials used for the manufacture of nitric acid. (3)

6.3 List FIVE uses of nitric acid. (5)

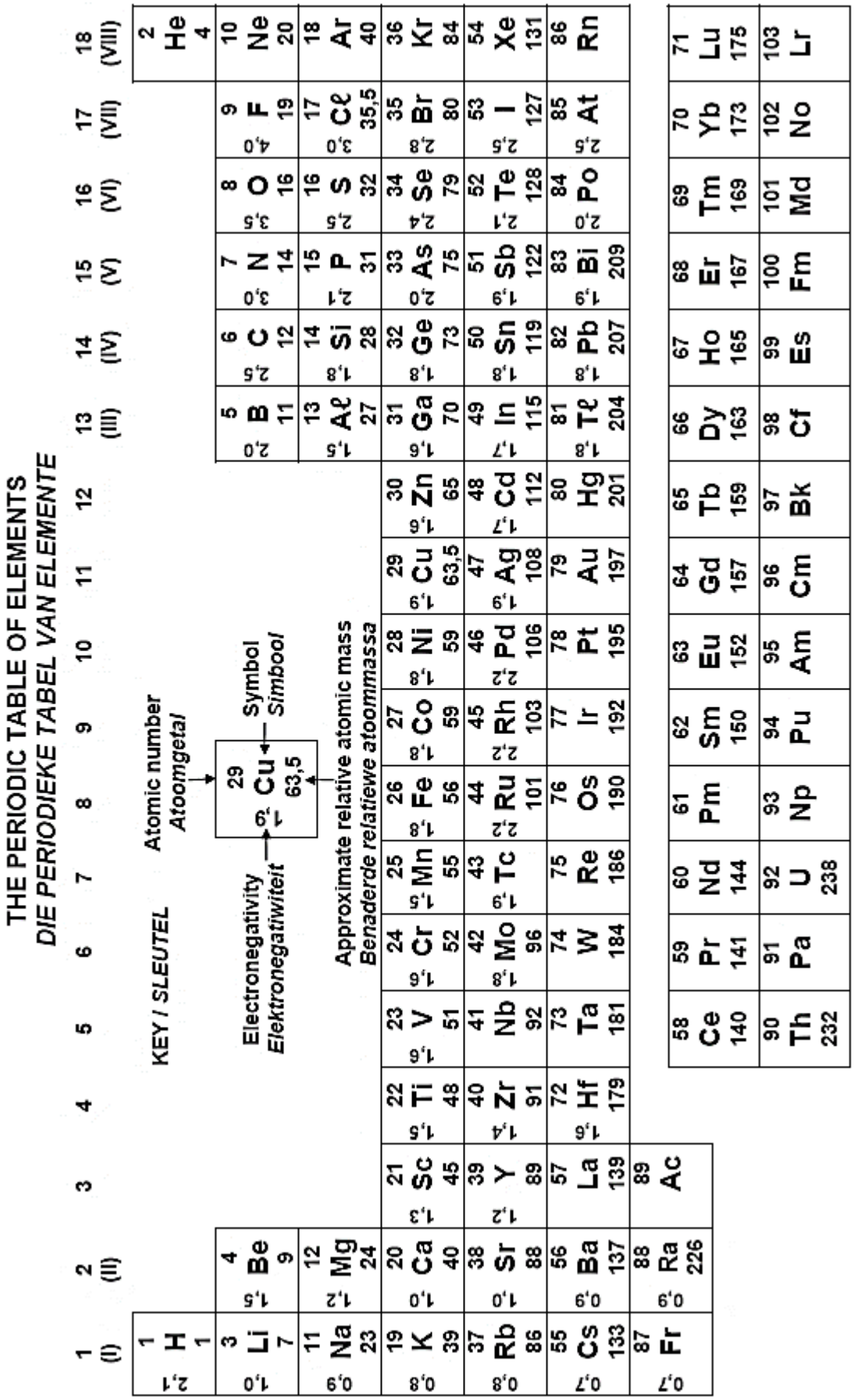
6.4 Complete the following reaction:

$4NH_3 + 3O_2 \rightarrow$ (2)

[25]

TOTAL: 100

PERIODIC TABLE



STEAM TABLE

p	t_s	v_g	h_f	h_{fg}	h_g	s_f	s_g
kPa	°C	m³/kg	kJ/kg	kJ/kg	kJ/kg	kJ/kg. K	kJ/kg. K
1,0	7,0	129,20	29	2 485	2 514	0,106	8,977
1,5	13,0	87,98	55	2 471	2 526	0,196	8,829
2,0	17,5	67,01	74	2 460	2 534	0,261	8,725
2,5	21,1	54,26	89	2 452	2 541	0,312	8,644
3,0	24,1	45,67	101	2 445	2 546	0,354	8,579
3,5	26,7	39,48	112	2 439	2 551	0,391	8,523
4,0	29,0	34,80	121	2 433	2 554	0,423	8,476
4,5	31,0	31,14	130	2 428	2 558	0,451	8,434
5,0	32,9	28,19	138	2 424	2 562	0,476	8,396
5,5	34,6	25,77	145	2 420	2 565	0,500	8,362
6,0	36,2	23,74	152	2 416	2 568	0,521	8,331
6,5	37,7	22,02	158	2 413	2 571	0,541	8,303
7,0	39,0	20,53	163	2 410	2 573	0,559	8,277
7,5	40,3	19,24	169	2 406	2 575	0,576	8,252
8,0	41,6	18,10	174	2 403	2 577	0,593	8,230
8,5	42,7	17,10	179	2 401	2 580	0,608	8,208
9,0	43,8	16,20	183	2 398	2 581	0,622	8,188
9,5	44,8	15,40	188	2 395	2 583	0,636	8,169
10	45,8	14,67	192	2 393	2 585	0,649	8,151
11	47,7	13,42	200	2 388	2 588	0,674	8,118
12	49,5	12,36	207	2 384	2 591	0,698	8,087
13	51,1	11,47	214	2 380	2 594	0,717	8,059
14	52,6	10,69	220	2 377	2 597	0,737	8,033
15	54,0	10,02	226	2 373	2 599	0,755	8,009
16	55,3	9,433	232	2 370	2 602	0,772	7,987
17	56,6	8,911	237	2 367	2 604	0,788	7,966
18	57,8	8,445	242	2 364	2 606	0,804	7,946
19	59,0	8,027	247	2 361	2 608	0,818	7,927
20	60,1	7,650	252	2 358	2 610	0,832	7,909
21	61,1	7,307	256	2 356	2 612	0,845	7,893
22	62,2	6,995	260	2 353	2 613	0,858	7,876
23	63,1	6,709	264	2 351	2 615	0,870	7,861
24	64,1	6,447	268	2 349	2 617	0,882	7,846
25	65,0	6,204	272	2 346	2 618	0,893	7,832
26	65,9	5,980	276	2 344	2 620	0,904	7,819
27	66,7	5,772	279	2 342	2 621	0,915	7,806
28	67,6	5,579	283	2 340	2 623	0,925	7,793
29	68,3	5,398	286	2 338	2 624	0,935	7,781
30	69,1	5,229	289	2 336	2 625	0,944	7,770
32	70,6	4,922	296	2 332	2 628	0,962	7,747
34	72,0	4,650	302	2 329	2 631	0,980	7,727
36	73,4	4,408	307	2 326	2 633	0,996	7,707
38	74,7	4,190	313	2 322	2 635	1,011	7,688
40	75,9	3,993	318	2 319	2 637	1,026	7,671
45	78,7	3,576	330	2 312	2 642	1,060	7,631
50	81,4	3,240	341	2 305	2 646	1,091	7,595
55	83,7	2,964	351	2 299	2 650	1,119	7,562
60	86,0	2,732	360	2 294	2 654	1,145	7,533
65	88,0	2,535	369	2 288	2 657	1,170	7,506
70	90,0	2,365	377	2 283	2 660	1,192	7,480

p	t_s	v_g	h_f	h_{fg}	h_g	s_f	s_g
kPa	°C	m³/kg	kJ/kg	kJ/kg	kJ/kg	kJ/kg. K	kJ/kg. K
75	91,8	2,217	385	2 279	2 664	1,213	7,457
80	93,5	2,087	392	2 274	2 666	1,233	7,435
85	95,2	1,972	399	2 270	2 669	1,252	7,415
90	96,7	1,869	405	2 266	2 671	1,270	7,395
95	98,2	1,777	412	2 262	2 674	1,287	7,377
100	99,6	1,694	418	2 258	2 676	1,303	7,360
110	102,3	1,549	429	2 251	2 680	1,333	7,328
120	104,8	1,428	439	2 244	2 683	1,361	7,300
130	107,1	1,325	449	2 238	2 687	1,387	7,272
140	109,3	1,236	458	2 232	2 690	1,411	7,247
150	111,4	1,159	467	2 226	2 693	1,434	7,223
160	113,3	1,091	475	2 221	2 696	1,455	7,202
170	115,2	1,031	483	2 216	2 699	1,475	7,181
180	116,9	0,977 2	491	2 211	2 702	1,494	7,162
190	118,6	0,929 0	498	2 206	2 704	1,513	7,144
200	120,2	0,885 4	505	2 202	2 707	1,530	7,127
210	121,8	0,845 9	511	2 197	2 708	1,547	7,111
220	123,3	0,809 8	518	2 193	2 711	1,563	7,095
230	124,7	0,776 8	524	2 189	2 713	1,578	7,080
240	126,1	0,746 5	530	2 185	2 715	1,593	7,066
250	127,4	0,718 4	535	2 181	2 716	1,607	7,052
260	128,7	0,692 5	541	2 177	2 718	1,621	7,039
270	130,0	0,668 4	546	2 174	2 720	1,634	7,026
280	131,2	0,646 0	551	2 170	2 721	1,647	7,014
290	132,4	0,625 1	557	2 167	2 724	1,660	7,002
300	133,5	0,605 6	561	2 163	2 724	1,672	6,991
310	134,7	0,587 2	566	2 160	2 726	1,683	6,980
320	135,8	0,570 0	571	2 157	2 728	1,695	6,969
330	136,8	0,553 8	576	2 154	2 730	1,706	6,959
340	137,9	0,538 5	580	2 150	2 730	1,717	6,949
350	138,9	0,524 0	584	2 147	2 731	1,727	6,939
360	139,9	0,510 3	589	2 144	2 733	1,738	6,930
370	140,8	0,497 4	593	2 141	2 734	1,748	6,921
380	141,8	0,485 1	597	2 139	2 736	1,757	6,912
390	142,7	0,473 4	601	2 136	2 737	1,767	6,903
400	143,6	0,462 2	605	2 133	2 738	1,776	6,894
410	144,5	0,451 6	609	2 130	2 739	1,786	6,886
420	145,4	0,441 5	612	2 128	2 740	1,795	6,878
430	146,3	0,431 8	616	2 125	2 741	1,803	6,870
440	147,1	0,422 6	620	2 122	2 742	1,812	6,862
450	147,9	0,413 8	624	2 120	2 744	1,820	6,855
460	148,7	0,405 3	627	2 117	2 744	1,829	6,847
470	149,5	0,397 2	630	2 115	2 745	1,837	6,840
480	150,3	0,389 4	634	2 112	2 746	1,845	6,833
490	151,1	0,381 9	637	2 110	2 747	1,853	6,826
500	151,8	0,374 7	640	2 107	2 747	1,860	6,819
520	153,3	0,361 1	647	2 103	2 750	1,875	6,806
540	154,8	0,348 5	653	2 098	2 751	1,890	6,793
560	156,2	0,336 7	659	2 094	2 753	1,904	6,781
580	157,5	0,325 7	665	2 089	2 754	1,918	6,769

INFORMATION SHEET 1

Mean molar heat capacities of gases at constant pressure [kJ/(kmol.K)]

K	H_2	N_2	CO	Air	O_2	$HC\ell$	$C\ell_2$	H_2O	CO_2	SO_2	SO_3	CH_4	C_2H_4	C_2H_6	NH_3
298	28.84	29.13	29.18	29.18	29.39	29.13	33.99	33.57	37.57	40.14	50.69	35.79	43.74	52.87	35.50
400	29.01	29.21	29.32	29.32	29.75	29.19	34.57	33.94	39.23	41.68	54.77	38.31	48.85	59.31	37.21
500	29.15	29.35	29.45	29.45	30.18	29.24	35.16	34.40	40.07	43.32	58.42	41.03	53.71	65.56	38.76
600	29.19	29.53	29.67	29.69	30.65	29.32	35.58	34.93	42.72	44.81	61.63	43.84	58.29	71.56	40.19
700	29.24	29.98	29.98	30.02	31.14	29.43	35.86	35.35	44.15	46.11	64.40	46.69	62.46	77.26	41.55
800	29.31	30.27	30.27	30.34	31.60	29.60	36.10	35.90	45.43	47.23	66.80	49.46	66.26	83.30	42.89
900	29.36	30.61	30.61	30.64	32.00	29.78	36.30	36.49	46.54	48.17	68.85	52.23	69.73	87.39	44.23
1000	29.46	30.93	30.93	30.94	32.37	30.00	36.45	37.08	47.56	49.01	70.27	54.66	72.91	91.93	45.56
1100	29.57	31.24	31.24	31.27	32.70	30.25	36.59	37.68	48.50	49.75	72.27	57.06	75.91	96.20	46.86
1200	29.69	31.56	31.56	31.56	33.02	30.49	36.74	38.29	49.35	50.43	73.72	59.43	78.66	100.00	48.16
1300	29.89	31.84	31.84	31.93	33.32	30.75	36.85	38.89	50.10	51.01	75.11	61.49	81.15	103.09	49.44
1400	30.07	32.09	32.09	32.13	33.60	31.00	36.94	39.45	50.82	51.53	76.36	63.47	83.51	107.17	50.71
1500	30.23	32.34	32.34	32.38	33.84			40.01	51.43						
1600	30.39	32.58	32.58	32.61	34.05			40.56	51.99						
1700	30.56	32.79	32.79	32.79	34.23			40.03	52.54						
1800	30.75	32.67	33.00	33.01	34.40			41.47	53.18						
1900	30.97	32.86	33.20	33.24	34.66			41.84	53.43						
2000	31.12	33.03	33.37	33.41	34.83			42.53	53.74						
2100	31.32	33.20	33.52	33.56	34.98			42.98	54.25						
2200	31.48	33.35	33.70	33.70	35.12			43.41	54.56						

Appendix 6A Properties of elements and inorganic compounds

Compound	Formula	Molecular weight	Normal melting point K	Normal boiling point K	Specific gravity (at K)	Physical state at 298 K		Enthalpies kJ/kmol: Heat of formation ΔH_f	Heat of fusion ΔH_{fus}	Heat of vaporization ΔH_{vap}	Heat of solution ΔH_{sol}	Molar heat capacities kJ/(kmol · K): Of the liquid	Of the solid $A + BT + CT^2$: A	$B \times 10^3$	$C \times 10^6$
1. Aluminum	Al	26.97	933	2328	2.70 (293)	c	1.	0	10,700	255,400	...	29.3	20.09	13.48	0
2. Ammonia	NH_3	17.03	195.5	239.8	...	g	2.	−45,900	5,600	23,400	−34,700				
3. Calcium carbonate	$CaCO_3$	100.09	−CO, 1098	...	2.71 (298)	c	3.	−1,207,700	...	...	...	...	82.46	49.81	−12.89
4. Calcium chloride	$CaCl_2$	110.99	1055	...	2.15 (288)	c	4.	−797,900	25,500	...	−77,900	103.4	70.74	16.16	0
5. Calcium hydroxide	$Ca(OH)_2$	74.10	$-H_2O$ 853	...	2.2 (293)	c	5.	−986,200	...	...	−15,100	...	89.58	0	0
6. Calcium oxide	CaO	56.08	2843	3123	3.32 (293)	c	6.	−635,900	51,200	...	−81,600	...	41.86	20.26	−4.52
7. Calcium sulfate	$CaSO_4$	136.14	...	...	2.96 (293)	c	7.	−1,418,000	28,000	...	−18,000	...	77.44	92.09	−6.57
8. Carbon (amorphous)	C	12.01	...	4473	1.8–2.1	...	8.								
9. Carbon (diamond)	C	12.01	3773	4473	3.51 (293)	c	9.	+1,900	...	...	...	...	9.04	12.81	−5.44
10. Carbon (graphite)	C	12.01	3933*	4473	2.26 (293)	c	10.	0	46,000	...	...	...	11.18	10.97	−4.90
11. Carbon dioxide	CO_2	44.01	216.6	194.7*	...	g	11.	−393,700	8,000	25,200†	−19,300				
12. Carbon monoxide	CO	28.01	68	81.7	...	g	12.	−110,600	840	6,030					
13. Chlorine	Cl_2	70.91	172.2	238.6	...	g	13.	0	6,400	20,400					
14. Copper	Cu	63.57	1356	2868	8.92 (293)	c	14.	0	13,000	304,800	...	31.4	22.77	6.11	0
15. Helium	He	4.00	1.0	4.3	...	g	15.	0	42	84					
16. Hydrogen	H_2	2.016	14.0	20.5	...	g	16.	0							
17. Hydrogen chloride	HCl	36.47	162	188	...	g	17.	−92,300	2,000	16,200	−74,500				
18. Hydrogen sulfide	H_2S	34.08	190.3	213.6	...	g	18.	−20,100	2,400	18,800	−19,300				
19. Iron	Fe	55.85	1808	3008	7.86 (293)	c	19.	0	14,900	354,100	...	34.1	17.29	26.71	0
20. Iron chloride	$FeCl_2$	162.22	555	588	2.80 (284)	c	20.	−403,500	86,200	50,400	−134,400				
21. Iron oxide	FeO	71.85	1693	...	5.7 (293)	c	21.	−270,400	32,200	...	...	...	52.83	6.24	−3.18
22. Iron oxide	Fe_2O_3	159.70	d. 1833	...	5.12 (293)	c	22.	−772,300	...	...	...	...	103.5	67.00	−17.71
23. Magnesium chloride	$MgCl_2$	95.23	985	1685	2.33 (293)	c	23.	−634,600	33,900	136,800	+150,400	...	72.42	15.78	0
24. Magnesium sulfate	$MgSO_4$	120.38	1458	...	2.66 (293)	c	24.	−1,276,500	14,700	...	+57,700	...	111.8	0	0

Appendix 7C Mean molar heat capacities of gases at constant pressure [kJ/(kmol · K)]

K	H_2	N_2	CO	Air	O_2	HCl	Cl_2	H_2O	CO_2	SO_2	SO_3	CH_4	C_2H_4	C_2H_6	NH_3
298	28.84	29.13	29.18	29.18	29.39	29.13	33.99	33.57	37.17	40.14	50.69	35.79	43.74	52.87	35.50
400	29.01	29.21	29.32	29.32	29.75	29.19	34.57	33.94	39.23	41.68	54.77	38.31	48.85	59.31	37.21
500	29.15	29.35	29.45	29.45	30.18	29.24	35.16	34.40	40.07	43.32	58.42	41.03	53.71	65.56	38.76
600	29.19	29.53	29.67	29.69	30.65	29.32	35.58	34.93	42.72	44.81	61.63	43.84	58.29	71.56	40.19
700	29.24	29.76	29.98	30.02	31.14	29.43	35.86	35.35	44.15	46.11	64.40	46.69	62.46	77.26	41.55
800	29.31	30.31	30.27	30.34	31.59	29.60	36.10	35.90	45.43	47.23	66.80	49.46	66.26	83.30	42.89
900	29.36	30.34	30.61	30.64	32.00	29.78	36.30	36.49	46.54	48.17	68.85	52.23	69.73	87.39	44.23
1000	29.46	30.64	30.93	30.94	32.37	30.00	36.45	37.08	47.56	49.01	70.27	54.66	72.91	91.93	45.56
1100	29.57	30.93	31.24	31.27	32.70	30.25	36.59	37.68	48.50	49.75	72.27	57.06	75.91	96.20	46.86
1200	29.69	31.22	31.56	31.56	33.02	30.49	36.74	38.29	49.35	50.43	73.72	59.34	78.66	100.15	48.16