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Department:
Higher Education and Training
REPUBLIC OF SOUTH AFRICA

NATIONAL CERTIFICATE

CHEMICAL PLANT OPERATION N5

(8050015)

5 August 2021 (X-paper)
09:00–12:00

Drawing instruments and nonprogrammable calculators may be used.

This question paper consists of 4 pages, 1 periodic table, 1steam table and 2 information sheets.

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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. Only use a black or blue pen.
6. Write neatly and legibly.

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QUESTION 1

Complete the following sentences by filling in the missing word or words. Write only the word or words next to the question number (1.1–1.10) in the ANSWER BOOK.

1.1 … is the form or manifestation of energy that flows from one object to another.

1.2 Calorie refers to the amount of … to raise the temperature of one gram of water from 14,5 °C to 15,5 °C.

1.3 Kopp's rule states that the total heat capacity of a compound is approximately equal to the sum of the heat capacities of the …

1.4 If steam contains … suspended in it, it is called wet steam.

1.5 In an impulse turbine, the entire available … from supply to exhaust occurs across the nozzles.

1.6 In axial-flow turbines the steam flow is … to the turbine axis.

1.7 When burners are burning with a/an …, it indicates that complete combustion has taken place.

1.8 In cyclones, the incoming dust-laden air receives a/an … on entrance to the cylinder.

1.9 Sulphuric acid and salt are roasted in a furnace to form … and sodium sulphate.

1.10 Tumbling mixers are used for dense solids in liquids and …

(10 × 2) **[20]**

QUESTION 2

2.1 Superheated steam at 500 °C and 4 000 kPa is concentrated at 100 kPa.

Determine the heat available for the heating process.

NOTE: Accept that the steam C_p = 1,97 kJ/kg.K. (5)

2.2 Write short notes on the following types of steam turbines:

2.2.1 Curtis turbine

2.2.2 Reaction turbine

(2 × 5) (10)
[15]

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QUESTION 3

3.1 Draw a labelled diagram of the closed-cycle gas turbine system. (6)

3.2 Briefly explain the operation of the horizontal rotating-cup atomising oil burner and draw a labelled diagram of this burner. (4 + 5) (9)

3.3 Write short notes on the following mixers:

3.3.1 Ribbon mixer

3.3.2 Muller mixer

3.3.3 Double-arm kneader

(3 × 5) (15)
[30]

QUESTION 4

4.1 The analysis of the off-gas (effluent) from a burner using C_4H_{10} is as follows:

N_2 = 75 mol%; O_2 = 13 mol%; CO_2 = 7 mol% and H_2O = 5 mol%.

Determine the ratio of moles of air to the moles of C_4H_{10} used in the burner. (10)

4.2 What are the FOUR conditions to be considered when maximising the chemical conversion of sulphur dioxide to sulphur trioxide? (4)

4.3 Discuss the operation of a cyclone. (6)
[20]

QUESTION 5

5.1 Describe *dry saturated steam*. (3)

5.2 Draw a fully labelled diagram of the production of 60% concentrated nitric acid from ammonia. (12)
[15]

TOTAL: 100

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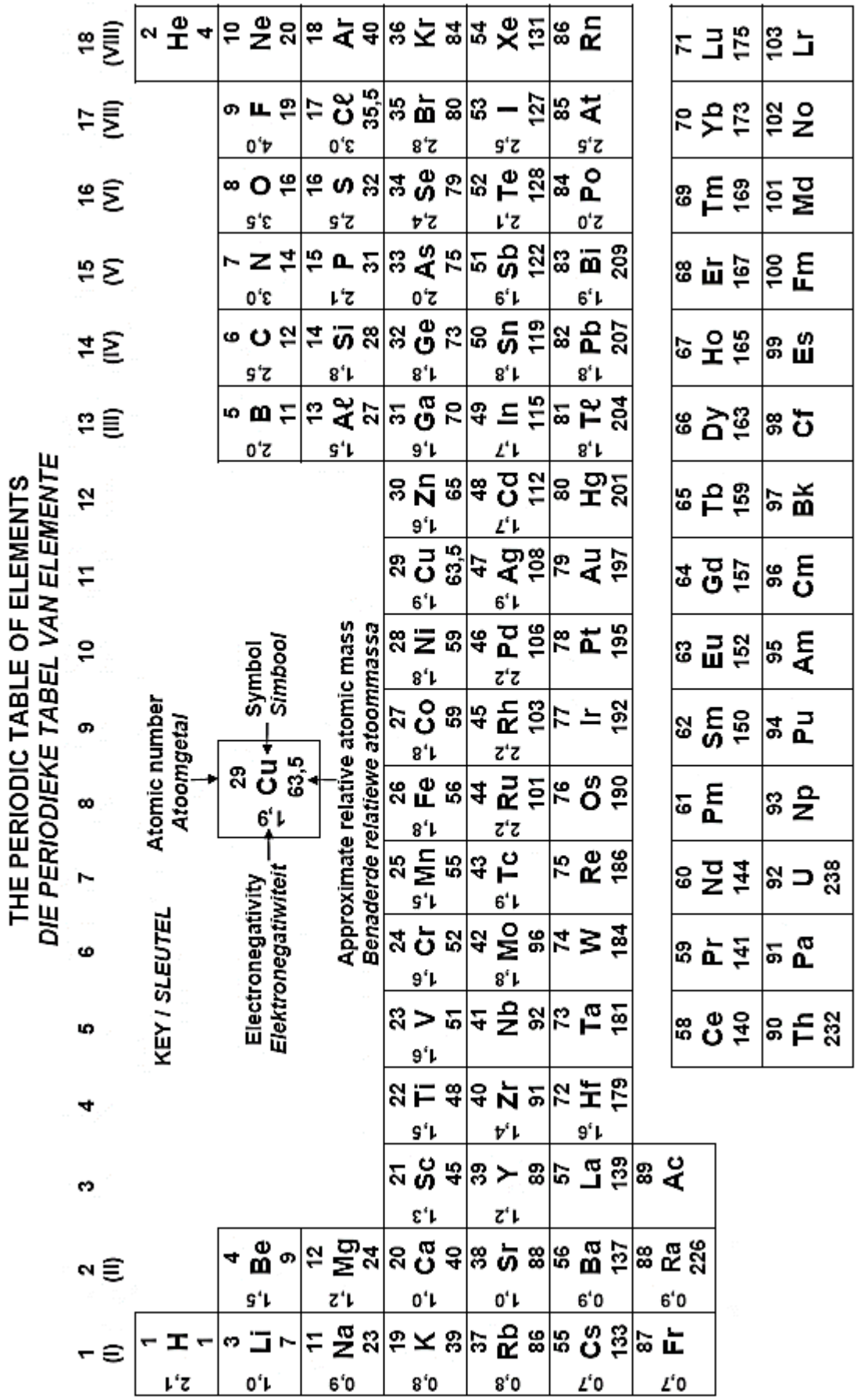
PERIODIC TABLE



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STEAM TABLE

p	t_s	v_g	h_f	h_{fg}	h_g	s_f	s_g	p	t_s	v_g	h_f	h_{fg}	h_g	s_f	s_g
kPa	°C	m^3/kg	kJ/kg	kJ/kg	kJ/kg	kJ/kg. K	kJ/kg. K	kPa	°C	m^3/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	75	91,8	2,217	385	2 279	2 664	1,213	7,457
1,5	13,0	87,98	55	2 471	2 526	0,196	8,829	80	93,5	2,087	392	2 274	2 666	1,233	7,435
2,0	17,5	67,01	74	2 460	2 534	0,261	8,725	85	95,2	1,972	399	2 270	2 669	1,252	7,415
2,5	21,1	54,26	89	2 452	2 541	0,312	8,644	90	96,7	1,869	405	2 266	2 671	1,270	7,395
3,0	24,1	45,67	101	2 445	2 546	0,354	8,579	95	98,2	1,777	412	2 262	2 674	1,287	7,377
3,5	26,7	39,48	112	2 439	2 551	0,391	8,523	100	99,6	1,694	418	2 258	2 676	1,303	7,360
4,0	29,0	34,80	121	2 433	2 554	0,423	8,476	110	102,3	1,549	429	2 251	2 680	1,333	7,328
4,5	31,0	31,14	130	2 428	2 558	0,451	8,434	120	104,8	1,428	439	2 244	2 683	1,361	7,300
5,0	32,9	28,19	138	2 424	2 562	0,476	8,396	130	107,1	1,325	449	2 238	2 687	1,387	7,272
5,5	34,6	25,77	145	2 420	2 565	0,500	8,362	140	109,3	1,236	458	2 232	2 690	1,411	7,247
6,0	36,2	23,74	152	2 416	2 568	0,521	8,331	150	111,4	1,159	467	2 226	2 693	1,434	7,223
6,5	37,7	22,02	158	2 413	2 571	0,541	8,303	160	113,3	1,091	475	2 221	2 696	1,455	7,202
7,0	39,0	20,53	163	2 410	2 573	0,559	8,277	170	115,2	1,031	483	2 216	2 699	1,475	7,181
7,5	40,3	19,24	169	2 406	2 575	0,576	8,252	180	116,9	0,977 2	491	2 211	2 702	1,494	7,162
8,0	41,6	18,10	174	2 403	2 577	0,593	8,230	190	118,6	0,929 0	498	2 206	2 704	1,513	7,144
8,5	42,7	17,10	179	2 401	2 580	0,608	8,208	200	120,2	0,885 4	505	2 202	2 707	1,530	7,127
9,0	43,8	16,20	183	2 398	2 581	0,622	8,188	210	121,8	0,845 9	511	2 197	2 708	1,547	7,111
9,5	44,8	15,40	188	2 395	2 583	0,636	8,169	220	123,3	0,809 8	518	2 193	2 711	1,563	7,095
10	45,8	14,67	192	2 393	2 585	0,649	8,151	230	124,7	0,776 8	524	2 189	2 713	1,578	7,080
11	47,7	13,42	200	2 388	2 588	0,674	8,118	240	126,1	0,746 5	530	2 185	2 715	1,593	7,066
12	49,5	12,36	207	2 384	2 591	0,698	8,087	250	127,4	0,718 4	535	2 181	2 716	1,607	7,052
13	51,1	11,47	214	2 380	2 594	0,717	8,059	260	128,7	0,692 5	541	2 177	2 718	1,621	7,039
14	52,6	10,69	220	2 377	2 597	0,737	8,033	270	130,0	0,668 4	546	2 174	2 720	1,634	7,026
15	54,0	10,02	226	2 373	2 599	0,755	8,009	280	131,2	0,646 0	551	2 170	2 721	1,647	7,014
16	55,3	9,433	232	2 370	2 602	0,772	7,987	290	132,4	0,625 1	557	2 167	2 724	1,660	7,002
17	56,6	8,911	237	2 367	2 604	0,788	7,966	300	133,5	0,605 6	561	2 163	2 724	1,672	6,991
18	57,8	8,445	242	2 364	2 606	0,804	7,946	310	134,7	0,587 2	566	2 160	2 726	1,683	6,980
19	59,0	8,027	247	2 361	2 608	0,818	7,927	320	135,8	0,570 0	571	2 157	2 728	1,695	6,969
20	60,1	7,650	252	2 358	2 610	0,832	7,909	330	136,8	0,553 8	576	2 154	2 730	1,706	6,959
21	61,1	7,307	256	2 356	2 612	0,845	7,893	340	137,9	0,538 5	580	2 150	2 730	1,717	6,949
22	62,2	6,995	260	2 353	2 613	0,858	7,876	350	138,9	0,524 0	584	2 147	2 731	1,727	6,939
23	63,1	6,709	264	2 351	2 615	0,870	7,861	360	139,9	0,510 3	589	2 144	2 733	1,738	6,930
24	64,1	6,447	268	2 349	2 617	0,882	7,846	370	140,8	0,497 4	593	2 141	2 734	1,748	6,921
25	65,0	6,204	272	2 346	2 618	0,893	7,832	380	141,8	0,485 1	597	2 139	2 736	1,757	6,912
26	65,9	5,980	276	2 344	2 620	0,904	7,819	390	142,7	0,473 4	601	2 136	2 737	1,767	6,903
27	66,7	5,772	279	2 342	2 621	0,915	7,806	400	143,6	0,462 2	605	2 133	2 738	1,776	6,894
28	67,6	5,579	283	2 340	2 623	0,925	7,793	410	144,5	0,451 6	609	2 130	2 739	1,786	6,886
29	68,3	5,398	286	2 338	2 624	0,935	7,781	420	145,4	0,441 5	612	2 128	2 740	1,795	6,878
30	69,1	5,229	289	2 336	2 625	0,944	7,770	430	146,3	0,431 8	616	2 125	2 741	1,803	6,870
32	70,6	4,922	296	2 332	2 628	0,962	7,747	440	147,1	0,422 6	620	2 122	2 742	1,812	6,862
34	72,0	4,650	302	2 329	2 631	0,980	7,727	450	147,9	0,413 8	624	2 120	2 744	1,820	6,855
36	73,4	4,408	307	2 326	2 633	0,996	7,707	460	148,7	0,405 3	627	2 117	2 744	1,829	6,847
38	74,7	4,190	313	2 322	2 635	1,011	7,688	470	149,5	0,397 2	630	2 115	2 745	1,837	6,840
40	75,9	3,993	318	2 319	2 637	1,026	7,671	480	150,3	0,389 4	634	2 112	2 746	1,845	6,833
45	78,7	3,576	330	2 312	2 642	1,060	7,631	490	151,1	0,381 9	637	2 110	2 747	1,853	6,826
50	81,4	3,240	341	2 305	2 646	1,091	7,595	500	151,8	0,374 7	640	2 107	2 747	1,860	6,819
55	83,7	2,964	351	2 299	2 650	1,119	7,562	520	153,3	0,361 1	647	2 103	2 750	1,875	6,806
60	86,0	2,732	360	2 294	2 654	1,145	7,533	540	154,8	0,348 5	653	2 098	2 751	1,890	6,793
65	88,0	2,535	369	2 288	2 657	1,170	7,506	560	156,2	0,336 7	659	2 094	2 753	1,904	6,781
70	90,0	2,365	377	2 283	2 660	1,192	7,480	580	157,5	0,325 7	665	2 089	2 754	1,918	6,769

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INFORMATION SHEET 1

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

K	H_2	N_2	CO	Air	O_2	HCℓ	$C\ell_2$	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						

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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_2 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

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