

APÉNDICE E

Propiedades termodinámicas del amoniaco

Tabla E.1 Amoniaco en saturación

T, °C	p, kPa	Volumen específico m ³ /kg			Entalpía kJ/kg			Entropía kJ/kg · K		
		Líquido Sat. v_f	Evap. v_{fg}	Vapor Sat. v_g	Líquido Sat. h_f	Evap. h_{fg}	Vapor Sat. h_g	Líquido Sat. s_f	Evap. s_{fg}	Vapor Sat. s_g
-50	40,88	0,001 424	2,6239	2,6254	-44,3	1,416,7	1,372,4	-0,1942	6,3502	6,1561
-46	51,55	0,001 434	2,1126	2,1140	-26,6	1,405,8	1,379,2	-0,1156	6,1902	6,0746
-44	57,69	0,001 439	1,9018	1,9032	-17,8	1,400,3	1,382,5	-0,0768	6,1120	6,0352
-42	64,42	0,001 444	1,7155	1,7170	-8,9	1,394,7	1,385,8	-0,0382	6,0349	5,9967
-40	71,77	0,001 449	1,5506	1,5521	0,0	1,389,0	1,389,0	0,0000	5,9589	5,9589
-38	79,80	0,001 454	1,4043	1,4058	8,9	1,383,3	1,392,2	0,0380	5,8840	5,9220
-36	88,54	0,001 460	1,2742	1,2757	17,8	1,377,6	1,395,4	0,0757	5,8101	5,8858
-34	98,05	0,001 465	1,1582	1,1597	26,8	1,371,8	1,398,5	0,1132	5,7372	5,8504
-32	108,37	0,001 470	1,0547	1,0562	35,7	1,365,9	1,401,6	0,1504	5,6652	5,8156
-30	119,55	0,001 476	0,9621	0,9635	44,7	1,360,0	1,404,6	0,1873	5,5942	5,7815
-28	131,64	0,001 481	0,8790	0,8805	53,6	1,354,0	1,407,6	0,2240	5,5241	5,7481
-26	144,70	0,001 487	0,8044	0,8059	62,6	1,347,9	1,410,5	0,2605	5,4548	5,7153
-24	158,78	0,001 492	0,7373	0,7388	71,6	1,341,8	1,413,4	0,2967	5,3864	5,6831
-22	173,93	0,001 498	0,6768	0,6783	80,7	1,335,6	1,416,2	0,3327	5,3188	5,6515
-20	190,22	0,001 504	0,6222	0,6237	89,7	1,329,3	1,419,0	0,3684	5,2520	5,6205
-18	207,71	0,001 510	0,5728	0,5743	98,8	1,322,9	1,421,7	0,4040	5,1860	5,5900
-16	226,45	0,001 515	0,5280	0,5296	107,8	1,316,5	1,424,4	0,4393	5,1207	5,5600
-14	246,51	0,001 521	0,4874	0,4889	116,9	1,310,0	1,427,0	0,4744	5,0561	5,5305
-12	267,95	0,001 528	0,4505	0,4520	126,0	1,303,5	1,429,5	0,5093	4,9922	5,5015
-10	290,85	0,001 534	0,4169	0,4185	135,2	1,296,8	1,432,0	0,5440	4,9290	5,4730
-8	315,25	0,001 540	0,3863	0,3878	144,3	1,290,1	1,434,4	0,5785	4,8664	5,4449
-6	341,25	0,001 546	0,3583	0,3599	153,5	1,283,3	1,436,8	0,6128	4,8045	5,4173
-4	368,90	0,001 553	0,3328	0,3343	162,7	1,276,4	1,439,1	0,6469	4,7432	5,3901
-2	398,27	0,001 559	0,3094	0,3109	171,9	1,269,4	1,441,3	0,6808	4,6825	5,3633
0	429,44	0,001 566	0,2879	0,2895	181,1	1,262,4	1,443,5	0,7145	4,6223	5,3369
2	462,49	0,001 573	0,2683	0,2698	190,4	1,255,2	1,445,6	0,7481	4,5627	5,3108
4	497,49	0,001 580	0,2502	0,2517	199,6	1,248,0	1,447,6	0,7815	4,5037	5,2852
6	534,51	0,001 587	0,2335	0,2351	208,9	1,240,6	1,449,6	0,8148	4,4451	5,2599
8	573,64	0,001 594	0,2182	0,2198	218,3	1,233,2	1,451,5	0,8479	4,3871	5,2350
10	614,95	0,001 601	0,2040	0,2056	227,6	1,225,7	1,453,3	0,8808	4,3295	5,2104
12	658,52	0,001 608	0,1910	0,1926	237,0	1,218,1	1,455,1	0,9136	4,2725	5,1861
14	704,44	0,001 616	0,1789	0,1805	246,4	1,210,4	1,456,8	0,9463	4,2159	5,1621
16	752,79	0,001 623	0,1677	0,1693	255,9	1,202,6	1,458,5	0,9788	4,1597	5,1385
18	803,66	0,001 631	0,1574	0,1590	265,4	1,194,7	1,460,0	1,0112	4,1039	5,1151
20	857,12	0,001 639	0,1477	0,1494	274,9	1,186,7	1,461,5	1,0434	4,0486	5,0920
22	913,27	0,001 647	0,1388	0,1405	284,4	1,178,5	1,462,9	1,0755	3,9937	5,0692

Tabla E.1 Amoníaco en saturación (continuación)

T, °C	P, kPa	Volumen específico m ³ /kg			Entalpía kJ/kg			Entropía kJ/kg · K		
		Líquido Sat.	Evap.	Vapor Sat.	Líquido Sat.	Evap.	Vapor Sat.	Líquido Sat.	Evap.	Vapor Sat.
		v_f	v_{fg}	v_g	h_f	h_{fg}	h_g	s_f	s_{fg}	s_g
24	972.19	0.001 655	0.1305	0.1322	294.0	1170.3	1464.3	1.1075	3.9392	5.0467
26	1033.97	0.001 663	0.1228	0.1245	303.6	1162.0	1465.6	1.1394	3.8850	5.0244
28	1098.71	0.001 671	0.1156	0.1173	313.2	1153.6	1466.8	1.1711	3.8312	5.0023
30	1166.49	0.001 680	0.1089	0.1106	322.9	1145.0	1467.9	1.2028	3.7777	4.9805
32	1237.41	0.001 689	0.1027	0.1044	332.6	1136.4	1469.0	1.2343	3.7246	4.9589
34	1311.55	0.001 698	0.0969	0.0986	342.3	1127.6	1469.9	1.2656	3.6718	4.9374
36	1389.03	0.001 707	0.0914	0.0931	352.1	1118.7	1470.8	1.2969	3.6192	4.9161
38	1469.92	0.001 716	0.0863	0.0880	361.9	1109.7	1471.5	1.3281	3.5669	4.8950
40	1554.33	0.001 726	0.0815	0.0833	371.7	1100.5	1472.2	1.3591	3.5148	4.8740
42	1642.35	0.001 735	0.0771	0.0788	381.6	1091.2	1472.8	1.3901	3.4630	4.8530
44	1734.09	0.001 745	0.0728	0.0746	391.5	1081.7	1473.2	1.4209	3.4112	4.8322
46	1829.65	0.001 756	0.0689	0.0707	401.5	1072.0	1473.5	1.4518	3.3595	4.8113
48	1929.13	0.001 766	0.0652	0.0669	411.5	1062.2	1473.7	1.4826	3.3079	4.7905
50	2032.62	0.001 777	0.0617	0.0635	421.7	1052.0	1473.7	1.5135	3.2561	4.7696

FUENTE: National Bureau of Standards Circular N° 142, *Tables of Thermodynamic Properties of Ammonia*.

Tabla E.2 Amoníaco sobrecalentado

P, kPa ($T_{\text{sat}}, ^\circ\text{C}$)		Temperatura, $^\circ\text{C}$											
		-20	-10	0	10	20	30	40	50	60	70	80	100
50 (-46,54)	v	2,4474	2,5481	2,6482	2,7479	2,8473	2,9464	3,0453	3,1441	3,2427	3,3413	3,4397	
	h	1,435 8	1,457 0	1,478 1	1,499 2	1,520 4	1,541 7	1,563 0	1,584 5	1,606 1	1,627 8	1,649 7	
	s	6,3256	6,4077	6,4865	6,5625	6,6360	6,7073	6,7766	6,8441	6,9099	6,9743	7,0372	
75 (-39,18)	v	1,6233	1,6915	1,7591	1,8263	1,8932	1,9597	2,0261	2,0923	2,1584	2,2244	2,2903	
	h	1,433 0	1,454 7	1,476 1	1,497 5	1,518 9	1,540 3	1,561 8	1,583 4	1,605 1	1,626 9	1,648 9	
	s	6,1190	6,2028	6,2828	-6,3597	6,4339	6,5058	6,5756	6,6434	6,7096	6,7742	6,8373	
100 (-33,61)	v	1,2110	1,2631	1,3145	1,3654	1,4160	1,4664	1,5165	1,5664	1,6163	1,6659	1,7155	1,8145
	h	1,430 1	1,452 2	1,474 1	1,495 7	1,517 3	1,538 9	1,560 5	1,582 2	1,604 1	1,626 0	1,648 0	1,692 6
	s	5,9695	6,0552	6,1366	6,2144	6,2894	6,3618	6,4321	6,5003	6,5668	6,6316	6,6950	6,8177
125 (-29,08)	v	0,9635	1,0059	1,0476	1,0889	1,1297	1,1703	1,2107	1,2509	1,2909	1,3309	1,3707	1,4501
	h	1,427 2	1,449 8	1,472 0	1,493 9	1,515 7	1,537 5	1,559 3	1,581 1	1,603 0	1,625 0	1,647 2	1,691 8
	s	5,8512	5,9389	6,0217	6,1006	6,1763	6,2494	6,3201	6,3887	6,4555	6,5206	6,5842	6,7072
150 (-25,23)	v	0,7984	0,8344	0,8697	0,9045	0,9388	0,9729	1,0068	1,0405	1,0740	1,1074	1,1408	1,2072
	h	1,424 1	1,447 3	1,469 8	1,492 1	1,514 1	1,536 1	1,558 0	1,580 0	1,602 0	1,624 1	1,646 3	1,691 1
	s	5,7526	5,8424	5,9266	6,0066	6,0831	6,1568	6,2280	6,2970	6,3641	6,4295	6,4933	6,6167
200 (-18,86)	v		0,6199	0,6471	0,6738	0,7001	0,7261	0,7519	0,7774	0,8029	0,8282	0,8533	0,9035
	h		1,442 0	1,465 5	1,488 4	1,510 9	1,533 2	1,555 5	1,577 7	1,599 9	1,622 2	1,644 6	1,689 6
	s		5,6863	5,7737	5,8559	5,9342	6,0091	6,0813	6,1512	6,2189	6,2849	6,3491	6,4732
250 (-13,67)	v		0,4910	0,5135	0,5354	0,5568	0,5780	0,5989	0,6196	0,6401	0,6605	0,6809	0,7212
	h		1,436 6	1,461 0	1,484 5	1,507 6	1,530 3	1,552 9	1,575 4	1,597 8	1,620 3	1,642 8	1,688 2
	s		5,5609	5,6517	5,7365	5,8165	5,8928	5,9661	6,0368	6,1052	6,1717	6,2365	6,3613
300 (-9,23)	v			0,4243	0,4430	0,4613	0,4792	0,4968	0,5143	0,5316	0,5488	0,5658	0,5997
	h			1,456 3	1,480 6	1,504 2	1,527 4	1,550 3	1,573 0	1,595 7	1,618 4	1,641 1	1,686 7
	s			5,5493	5,6366	5,7186	5,7963	5,8707	5,9423	6,0114	6,0785	6,1437	6,2693
350 (-5,35)	v			0,3605	0,3770	0,3929	0,4086	0,4239	0,4391	0,4541	0,4689	0,4837	0,5129
	h			1,451 5	1,476 5	1,500 7	1,524 4	1,547 6	1,570 7	1,593 6	1,616 5	1,639 3	1,685 2
	s			5,4600	5,5502	5,6342	5,7135	5,7890	5,8615	5,9314	5,9990	6,0647	6,1910
400 (-1,89)	v			0,3125	0,3274	0,3417	0,3556	0,3692	0,3826	0,3959	0,4090	0,4220	0,4478
	h			1,446 5	1,472 4	1,497 2	1,521 3	1,544 9	1,568 3	1,591 5	1,614 5	1,637 6	1,683 7
	s			5,3803	5,4735	5,5597	5,6405	5,7173	5,7907	5,8613	5,9296	5,9957	6,1228
450 (1,26)	v			0,2752	0,2887	0,3017	0,3143	0,3266	0,3387	0,3506	0,3624	0,3740	0,3971
	h			1,441 3	1,468 1	1,493 6	1,518 2	1,542 2	1,565 9	1,589 3	1,612 6	1,635 8	1,682 2
	s			5,3078	5,4042	5,4926	5,5752	5,6532	5,7275	5,7989	5,8678	5,9345	6,0623
		20	30	40	50	60	70	80	100	120	140	160	180
500 (4,14)	v	0,2698	0,2813	0,2926	0,3036	0,3144	0,3251	0,3357	0,3565	0,3771	0,3975		
	h	1,489 9	1,515 0	1,539 5	1,563 4	1,587 1	1,610 6	1,634 0	1,680 7	1,727 5	1,774 7		
	s	5,4314	5,5157	5,5950	5,6704	5,7425	5,8120	5,8793	6,0079	6,1301	6,2472		
600 (9,29)	v	0,2217	0,2317	0,2414	0,2508	0,2600	0,2691	0,2781	0,2957	0,3130	0,3302		
	h	1,482 4	1,508 6	1,533 8	1,558 5	1,582 7	1,606 6	1,630 4	1,677 7	1,724 9	1,772 4		
	s	5,3222	5,4102	5,4923	5,5697	5,6436	5,7144	5,7826	5,9129	6,0363	6,1541		
700 (13,81)	v	0,1874	0,1963	0,2048	0,2131	0,2212	0,2291	0,2369	0,2522	0,2672	0,2821		
	h	1,474 5	1,501 9	1,528 1	1,553 4	1,578 2	1,602 6	1,626 8	1,674 6	1,722 4	1,770 2		
	s	5,2259	5,3179	5,4029	5,4826	5,5582	5,6303	5,6997	5,8316	5,9562	6,0749		
800 (17,86)	v	0,1615	0,1696	0,1773	0,1848	0,1920	0,1991	0,2060	0,2196	0,2329	0,2459	0,2589	
	h	1,466 3	1,495 0	1,522 2	1,548 3	1,573 7	1,598 6	1,623 1	1,671 6	1,719 8	1,768 0	1,816 4	
	s	5,1387	5,2351	5,3232	5,4053	5,4827	5,5562	5,6268	5,7603	5,8861	6,0057	6,1202	
900 (21,54)	v		0,1488	0,1559	0,1627	0,1693	0,1757	0,1820	0,1942	0,2061	0,2178	0,2294	
	h		1,488 0	1,516 2	1,543 0	1,569 1	1,594 4	1,619 4	1,668 5	1,717 1	1,765 7	1,814 4	
	s		5,1593	5,2508	5,3354	5,4147	5,4897	5,5614	5,6968	5,8237	5,9442	6,0594	
1000 (24,91)	v		0,1321	0,1388	0,1450	0,1511	0,1570	0,1627	0,1739	0,1847	0,1954	0,2058	0,2162
	h		1,480 6	1,510 0	1,537 7	1,564 4	1,590 3	1,615 6	1,665 4	1,714 5	1,763 4	1,812 4	1,861 7
	s		5,0889	5,1840	5,2713	5,3525	5,4292	5,5021	5,6392	5,7674	5,8888	6,0047	6,1159
1200 (30,96)	v			0,1129	0,1185	0,1238	0,1289	0,1338	0,1434	0,1526	0,1616	0,1705	0,1792
	h			1,497 1	1,526 6	1,554 7	1,581 7	1,608 0	1,659 2	1,709 2	1,758 9	1,808 5	1,858 2
	s			5,0629	5,1560	5,2416	5,3215	5,3970	5,5379	5,6687	5,7919	5,9091	6,0214
	v			0,0944	0,0995	0,1042	0,1088	0,1132	0,1216	0,1297	0,1376	0,1452	0,1528

Tabla E.2 Amoniaco sobrecalentado (continuación)

p , kPa (T_{sat} , °C)		Temperatura, °C											
		20	30	40	50	60	70	80	100	120	140	160	180
1400 (36,28)	h			1.483 4	1.515 1	1.544 7	1.573 0	1.600 2	1.652 8	1.703 9	1.754 3	1.804 5	1.854 7
	s			4,9534	5,0530	5,1434	5,2270	5,3053	5,4501	5,5836	5,7087	5,8273	5,9406
	v				0,0851	0,0895	0,0937	0,0977	0,1053	0,1125	0,1195	0,1263	0,1330
1600 (41,05)	h				1.502 9	1.534 4	1.564 0	1.592 3	1.646 4	1.698 5	1.749 7	1.800 5	1.851 2
	s				4,9584	5,0543	5,1419	5,2232	5,3722	5,5084	5,6355	5,7555	5,8699
	v				0,0739	0,0781	0,0820	0,0856	0,0926	0,0992	0,1055	0,1116	0,1177
1800 (45,39)	h				1.490 0	1.523 5	1.554 6	1.584 1	1.639 8	1.693 1	1.745 1	1.796 5	1.847 7
	s				4,8693	4,9715	5,0635	5,1482	5,3018	5,4409	5,5699	5,6914	5,8069
	v				0,0648	0,0688	0,0725	0,0760	0,0824	0,0885	0,0943	0,0999	0,1054
2000 (49,38)	h				1.476 1	1.512 0	1.544 9	1.575 6	1.633 2	1.687 6	1.740 4	1.792 4	1.844 1
	s				4,7834	4,8930	4,9902	5,0786	5,2371	5,3793	5,5104	5,6333	5,7499

FUENTE: National Bureau of Standards Circular N° 142, *Tables of Thermodynamic Properties of Ammonia*.