C A P I T U L O V

PROPIEDADES FISICAS DE LAS SUBSTANCIAS

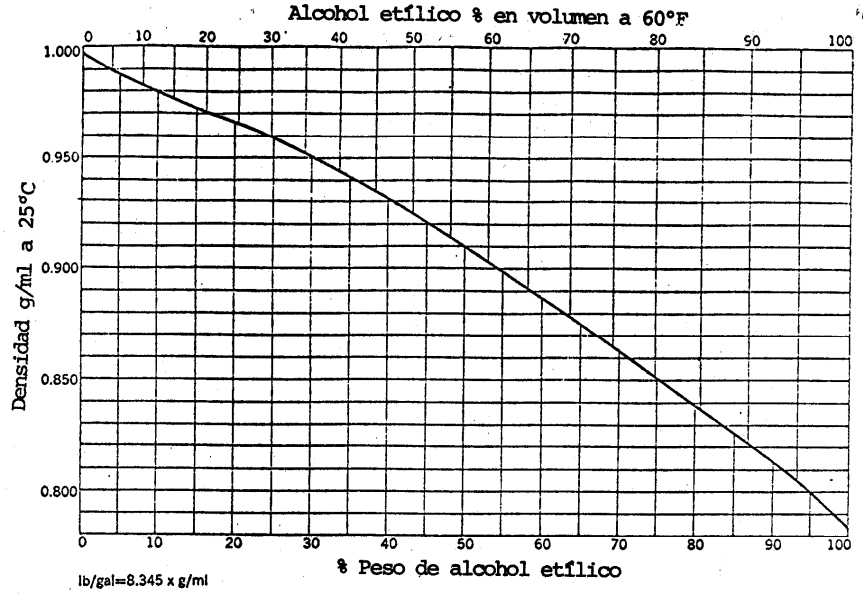
ALCOHOL ETILICO - AGUA

5.1.- DENSIDAD DE LA SOLUCION DE ALCOHOL ETILICO Y AGUA A VARIAS TEMPERATURAS

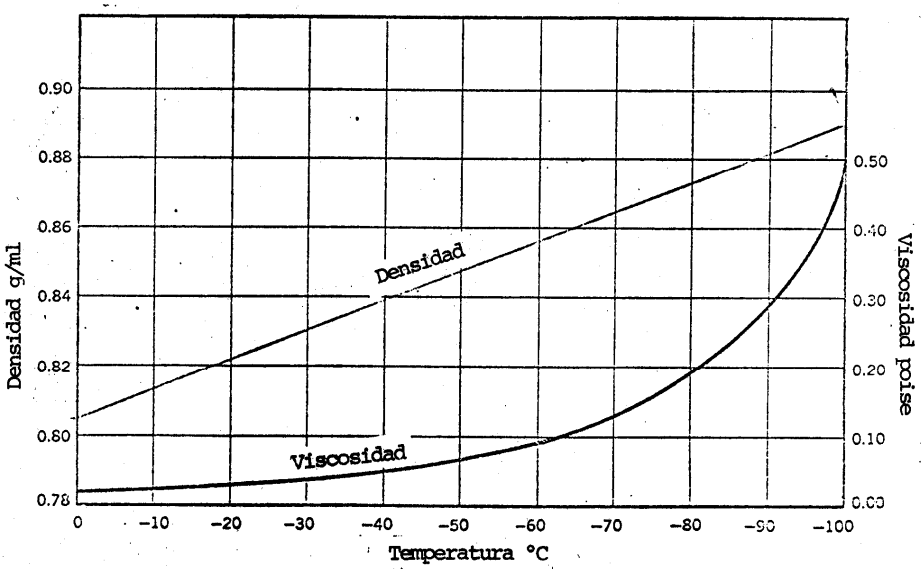
% alcohol en peso	Densidad (g/ml) a: 10°C	15°C	20°C	25°C	30°C	35°C	40°C
0	0.99973	0.99913	0.99823	0.99708	0.99568	0.99406	0.99225
1	785	725	636	520	379	217	034
2	602	542	453	336	194	031	.98846
3	426	365	275	157	014	.98849	663
4	258	195	103	.98984	.98839	672	485
5	098	032	.98938	817	670	501	311
6	.98946	.98877	780	656	507	335	142
7	801	729	627	500	347	172	.97975
8	650	584	478	346	189	009	808
9	524	442	331	193	031	.97846	641
10	393	304	187	043	.97875	685	475
11	267	171	047	.97897	725	527	312
12	145	041	.97910	753	573	371	150
13	026	.97914	775	611	424	216	.96989
14	.97911	790	643	472	278	063	829
15	800	669	514	334	133	.96911	670
16	692	552	387	199	.96990	760	512
17	583	433	259	062	844	607	352
18	473	313	129	.96923	697	452	189
19	363	191	.96997	782	547	294	023
20	252	068	864	639	395	134	.95856
21	139	.96944	729	495	242	.95973	687
22	024	818	592	348	087	809	516
23	.96907	689	453	199	.95929	643	343
24	787	558	312	048	769	476	168
25	665	424	168	.95895	607	306	.94991
26	539	287	020	738	442	133	810
27	406	144	.95867	576	272	.94955	625
28	268	.95996	710	410	098	774	438
29	125	844	548	241	.94922	550	248
30	.95977	686	382	067	741	403	055
31	823	524	212	.94890	557	214	.93860
32	665	357	038	709	370	021	662
33	502	186	.94860	525	180	.93825	461
34	334	011	679	337	.93986	626	257
35	162	.94832	494	146	790	425	051
36	.94986	650	306	.93952	591	221	.92843
37	805	464	114	756	390	016	634
38	620	273	.93919	556	186	.92808	422
39	431	079	720	353	.92979	597	208
40	238	.93882	518	148	770	385	.91992
41	042	682	314	.92940	558	170	774
42	.93842	478	107	729	344	.91952	554
43	639	271	.92897	516	128	733	332
44	433	062	685	301	.91910	513	108
45	226	.92852	472	085	692	291	.90884
46	017	640	257	.91868	472	069	660
47	.92806	426	041	649	250	.90845	434
48	593	211	.91823	429	028	621	207
49	379	.91995	604	208	.90805	396	.89979

% alcohol en peso	Densidad (g/ml) a: 10°C	15°C	20°C	25°C	30°C	35°C	40°C
50	0.92162	0.91776	0.91384	0.90985	0.90580	0.90168	0.89750
51	.91943	555	160	760	353	.89940	519
52	723	333	.90936	534	125	710	283
53	502	110	711	307	.89895	479	046
54	279	.90885	485	079	657	248	.88823
55	055	659	258	.89850	437	016	589
56	.90831	433	031	621	206	.88784	356
57	607	207	.89803	392	.88975	552	122
58	381	.89980	574	162	744	319	.87888
59	154	752	344	.88931	512	085	653
60	.89927	523	113	699	278	.87851	417
61	698	293	.88882	466	044	615	180
62	468	062	650	233	.87809	379	.86943
63	237	.88830	417	.87998	574	142	705
64	006	597	183	763	337	.86905	466
65	.88774	364	.87948	527	100	667	227
66	541	130	713	291	.86863	429	.85987
67	308	.87895	477	054	625	190	747
68	074	660	241	.86817	387	.85950	507
69	.87839	424	004	579	148	710	266
70	602	187	.86766	340	.85908	470	025
71	365	.86949	527	100	667	228	.84783
72	127	710	287	.85859	426	.84986	540
73	.86888	470	047	618	184	743	297
74	648	229	.85806	376	.84941	500	053
75	408	.85988	564	134	698	257	.83809
76	168	747	322	.84891	455	013	564
77	.85927	505	079	647	211	.83768	319
78	685	262	.84835	403	.83966	525	074
79	442	018	590	158	720	277	.82827
80	197	.84772	344	.83911	473	029	578
81	.84950	525	096	664	224	.82780	329
82	702	277	.83848	415	.82974	530	079
83	453	028	599	164	724	279	.81828
84	203	.83777	348	.82913	473	027	576
85	.83951	525	095	660	220	.81774	322
86	697	271	.82840	405	.81965	519	067
87	441	014	583	148	708	262	.80811
88	181	.82754	323	.81888	448	003	552
89	.82919	492	062	626	186	.80742	291
90	654	227	.81797	362	.80922	478	028
91	386	.81959	529	094	655	211	.79761
92	114	688	257	.80823	384	.79941	491
93	.81839	413	.80983	549	111	669	220
94	561	134	705	272	.79835	393	.78947
95	278	.80852	424	.79991	555	114	670
96	.80991	566	138	706	271	.78831	388
97	698	274	.79846	415	.78981	542	100
98	399	.79975	547	117	684	247	.77806
99	094	670	243	.78814	382	.77946	507
100	.79784	360	.78534	506	075	641	203

5.2.- CONVERSION DE LA DENSIDAD A CONCENTRACION



5.3.- DENSIDAD Y VISCOSIDAD DE ALCOHOL PURO A BAJAS TEMPERATURAS

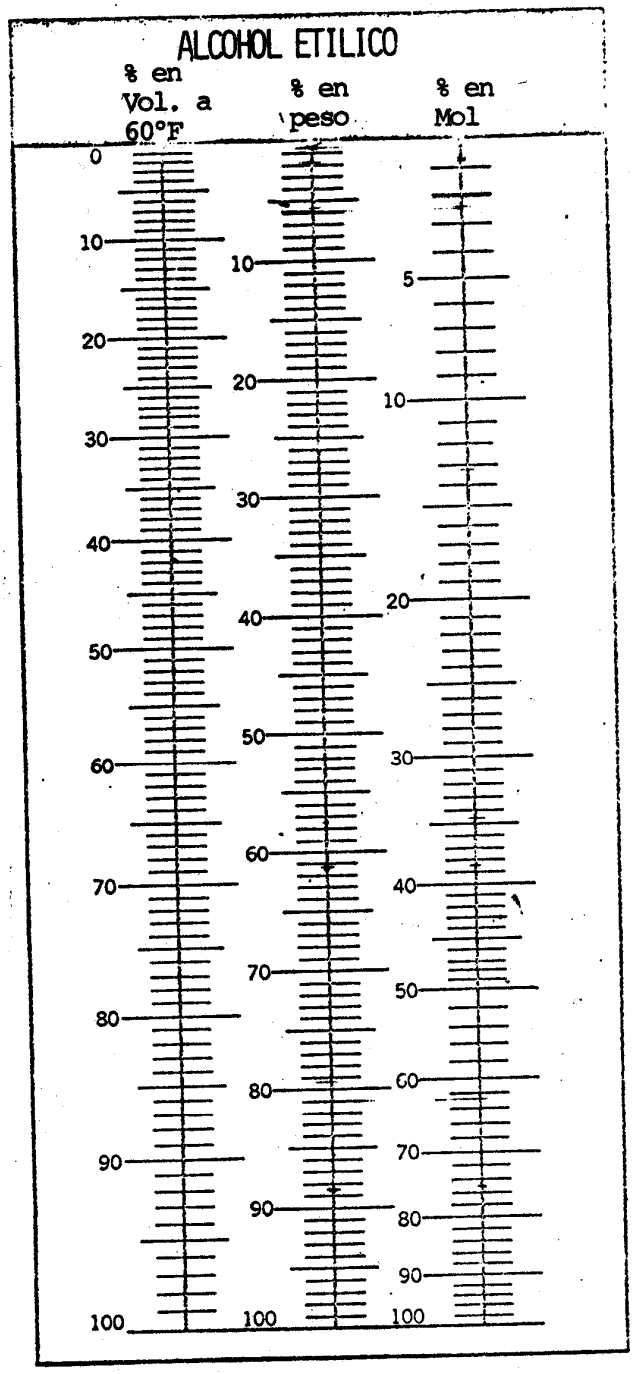


5.4.- TABLA DE CONVERSION DE PORCIENTO EN PESO Y VOLUMEN EN SOLUCIONES DE ALCOHOL ETILICO Y AGUA

* = % a ser convertido

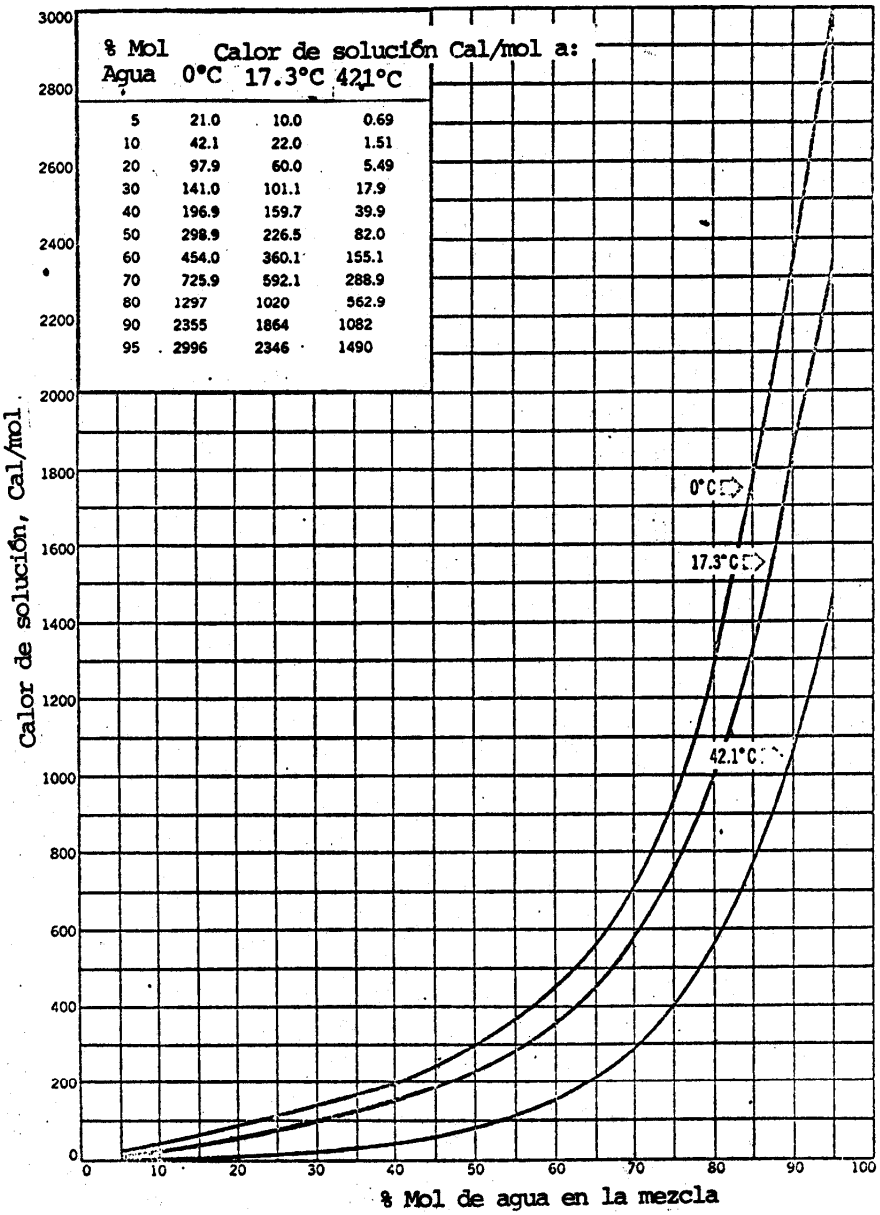
%Vol	*	%Peso	%Vol.	*	%Peso	%Vol.	*	%Peso	%Vol.	*	%Peso
1.257	1	0.795	31.555	26	21.285	58.844	51	43.428	82.121	76	68.982
2.510	2	1.593	32.719	27	22.127	59.852	52	44.374	82.967	77	70.102
3.758	3	2.392	33.879	28	22.973	60.854	53	45.326	83.805	78	71.234
5.002	4	3.194	35.033	29	23.820	61.850	54	46.283	84.636	79	72.375
6.243	5	3.998	36.181	30	24.670	62.837	55	47.245	85.459	80	73.526
7.479	6	4.804	37.323	31	25.524	63.820	56	48.214	86.275	81	74.686
8.712	7	5.612	38.459	32	26.382	64.798	57	49.187	87.083	82	75.858
9.943	8	6.422	39.590	33	27.242	65.768	58	50.167	87.885	83	77.039
11.169	9	7.234	40.716	34	28.104	66.732	59	51.154	88.678	84	78.233
12.393	10	8.047	41.832	35	28.971	67.690	60	52.147	89.464	85	79.441
13.613	11	8.862	42.944	36	29.842	68.641	61	53.146	90.240	86	80.662
14.832	12	9.679	44.050	37	30.717	69.586	62	54.152	91.008	87	81.897
16.047	13	10.497	45.149	38	31.596	70.523	63	55.165	91.766	88	83.144
17.259	14	11.317	46.242	39	32.478	71.455	64	56.184	92.517	89	84.408
18.469	15	12.138	47.328	40	33.364	72.380	65	57.208	93.254	90	85.689
19.676	16	12.961	48.407	41	34.254	73.299	66	58.241	93.982	91	86.989
20.880	17	13.786	49.480	42	35.150	74.211	67	59.279	94.700	92	88.310
22.081	18	14.612	50.545	43	36.050	75.117	68	60.325	95.407	93	89.652
23.278	19	15.440	51.605	44	36.955	76.016	69	61.379	96.103	94	91.025
24.472	20	16.269	52.658	45	37.865	76.909	70	62.441	96.787	95	92.423
25.662	21	17.100	53.705	46	38.778	77.794	71	63.511	97.459	96	93.851
26.849	22	17.933	54.746	47	39.697	78.672	72	64.588	98.117	97	95.315
28.032	23	18.768	55.780	48	40.622	79.544	73	65.674	98.759	98	96.820
29.210	24	19.604	56.808	49	41.551	80.410	74	66.768	99.386	99	98.381
30.388	25	20.443	57.830	50	42.487	81.269	75	67.870	100.000	100	100.000

5.5.- ESCALA DE CONVERSION MOL- VOLUMEN Y PESO EN PORCIENTO PARA MEZCLAS ALCOHOL ETILICO Y AGUA.

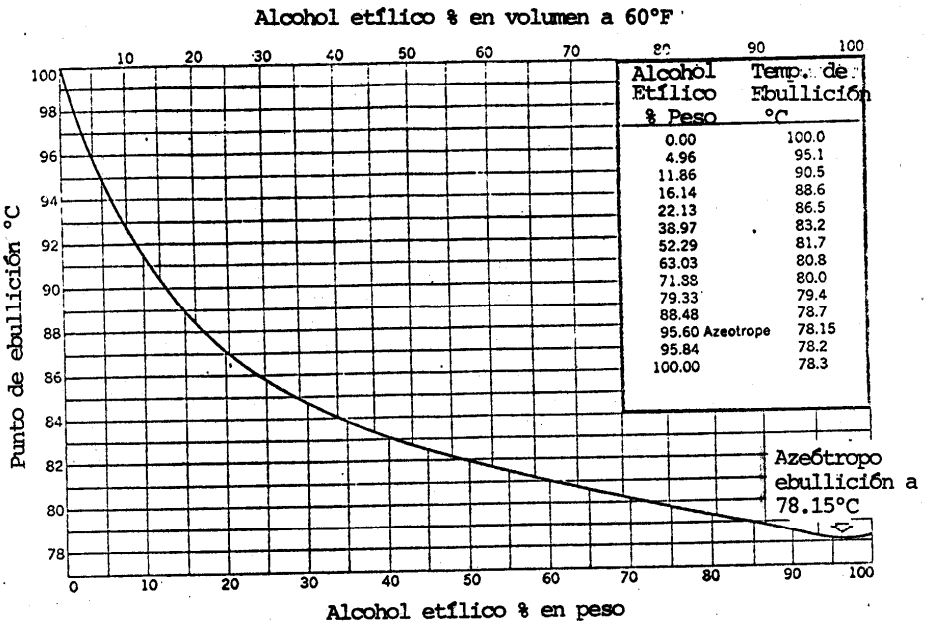


5.6.- CALOR DE SOLUCION DE ALCOHOL ETILICO EN AGUA

% Mol Agua	Calor de solución Cal/mol a: 0°C	17.3°C	42.1°C
5	21.0	10.0	0.69
10	42.1	22.0	1.51
20	97.9	60.0	5.49
30	141.0	101.1	17.9
40	196.9	159.7	39.9
50	298.9	226.5	82.0
60	454.0	360.1	155.1
70	725.9	592.1	288.9
80	1297	1020	562.9
90	2355	1864	1082
95	2996	2346	1490

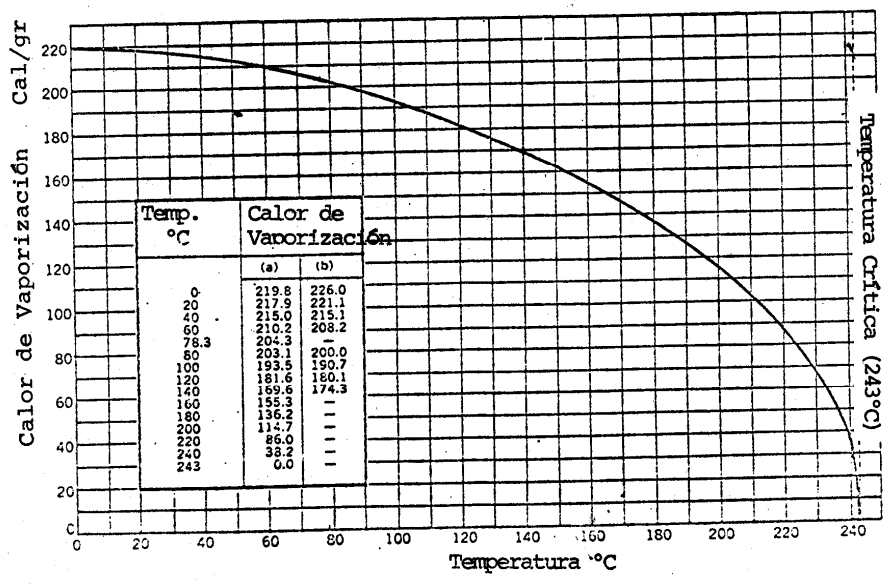


5.7.- PUNTOS DE EBULLICION DE SOLUCIONES DE ALCOHOL ETILICO Y AGUA



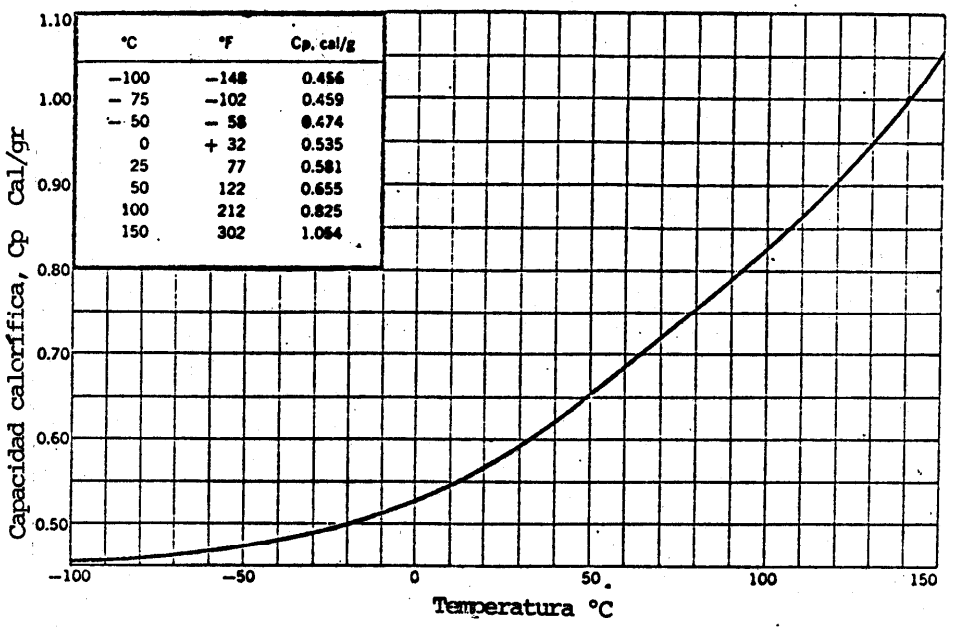
Alcohol Etílico % Peso	Temp. de Ebullición °C
0.00	100.0
4.96	95.1
11.86	90.5
16.14	88.6
22.13	86.5
38.97	83.2
52.29	81.7
63.03	80.8
71.88	80.0
79.33	79.4
88.48	78.7
95.60 Azeotrope	78.15
95.84	78.2
100.00	78.3

5.8.- CALOR LATENTE DE VAPORIZACION DE ALCOHOL ETILICO



Temp. °C	Calor de Vaporización (a)	(b)
0	219.8	226.0
20	217.9	221.1
40	215.0	215.1
60	210.2	208.2
78.3	204.3	—
80	203.1	200.0
100	193.5	190.7
120	181.6	180.1
140	169.6	174.3
160	155.3	—
180	136.2	—
200	114.7	—
220	86.0	—
240	38.2	—
243	0.0	—

5.9.- CAPACIDAD CALORIFICA, Cp DE ALCOHOL ETILICO Y AGUA

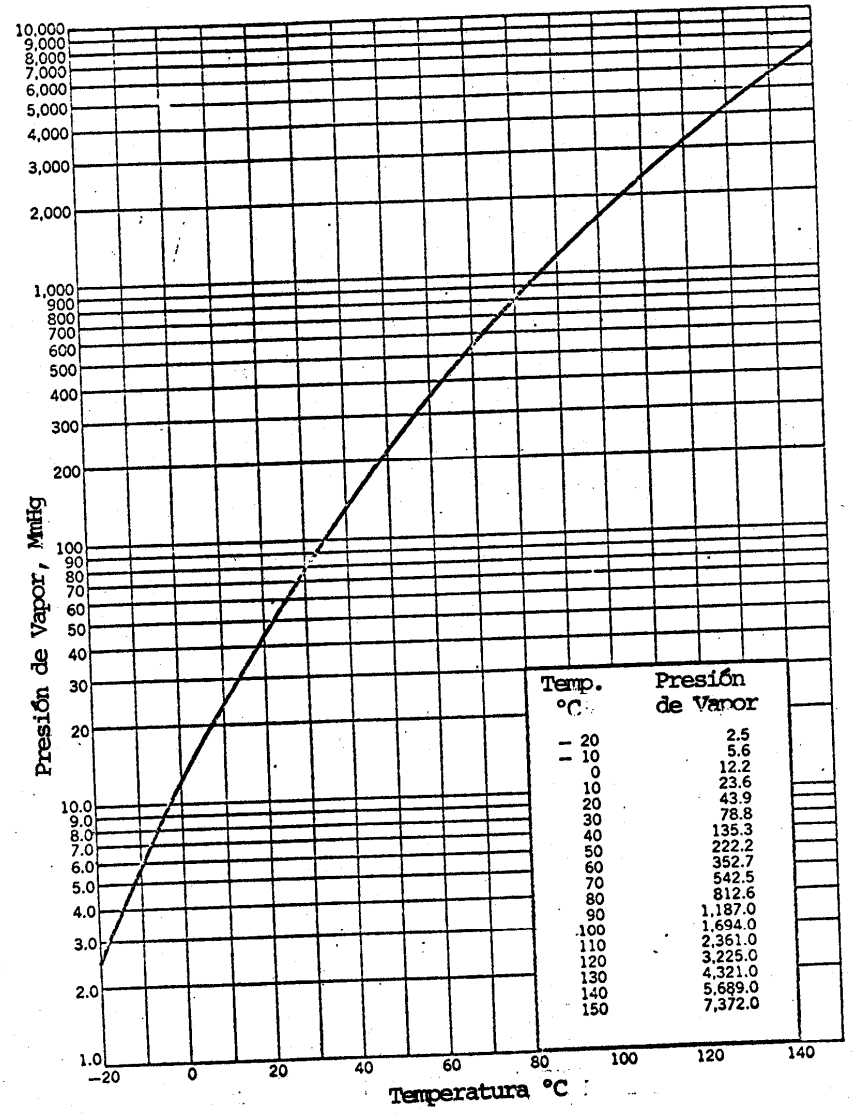


5.10.- PRESIONES PARCIALES DE LAS SOLUCIONES DE ALCOHOL ETILICO Y AGUA A 20°C

concentracion de alcohol — presion parcial mmHg

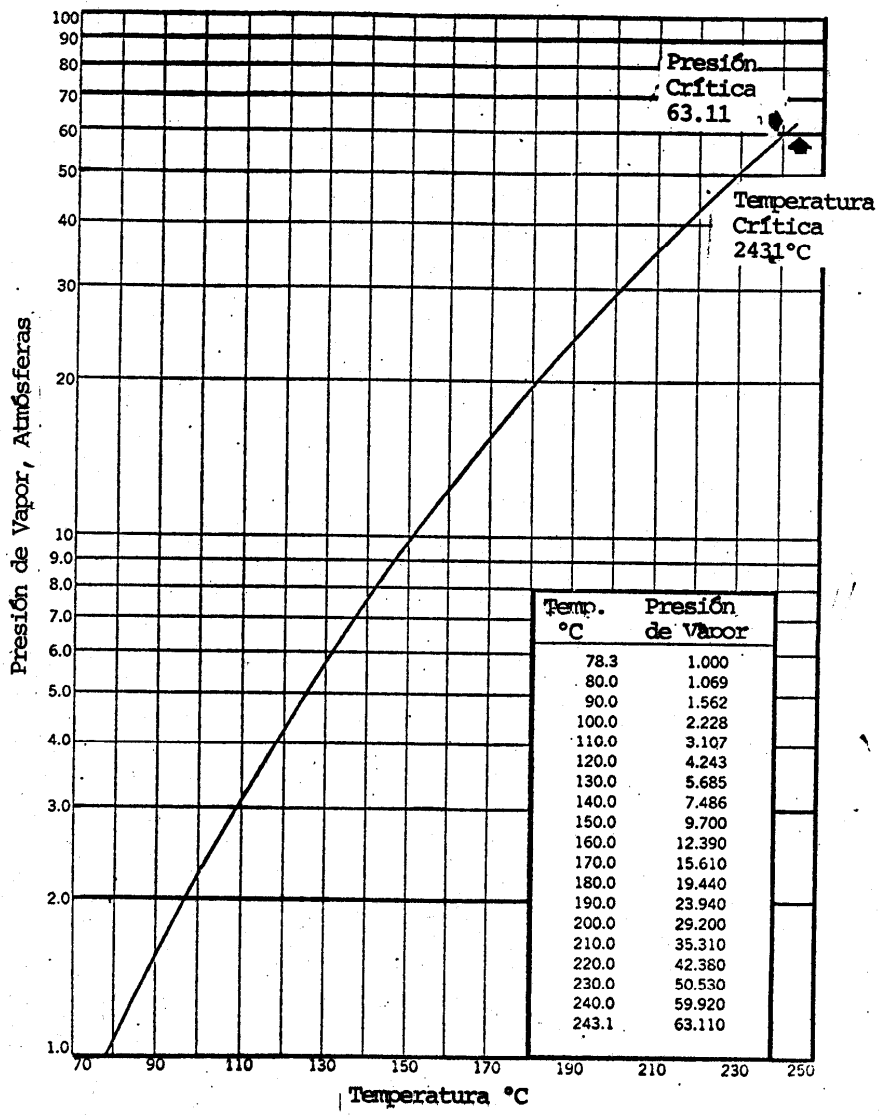
% Peso	% Mol	Alcohol	Agua
0	0.00	0	17.5
10	4.17	6.7*	16.8
20	8.91	12.6*	15.9
30	14.36	17.1*	15.1
40	20.68	20.7	14.7
50	28.12	23.5	14.5
60	36.97	25.6	14.1
70	47.72	28.0	13.1
80	61.02	31.2	11.3
90	77.87	35.8	7.5
98	95.04	42.3	1.9
100	100.00	43.6	0.0

5.11.- PRESION DE VAPOR DE ALCOHOL ETILICO -20°C A 150°C



Temp. °C	Presión de Vapor
− 20	2.5
− 10	5.6
0	12.2
10	23.6
20	43.9
30	78.8
40	135.3
50	222.2
60	352.7
70	542.5
80	812.6
90	1,187.0
100	1,694.0
110	2,361.0
120	3,225.0
130	4,321.0
140	5,689.0
150	7,372.0

5.12.- PRESION DE VAPOR DE ALCOHOL ETILICO A UNA ATMOSFERA DE PRESION CRITICA

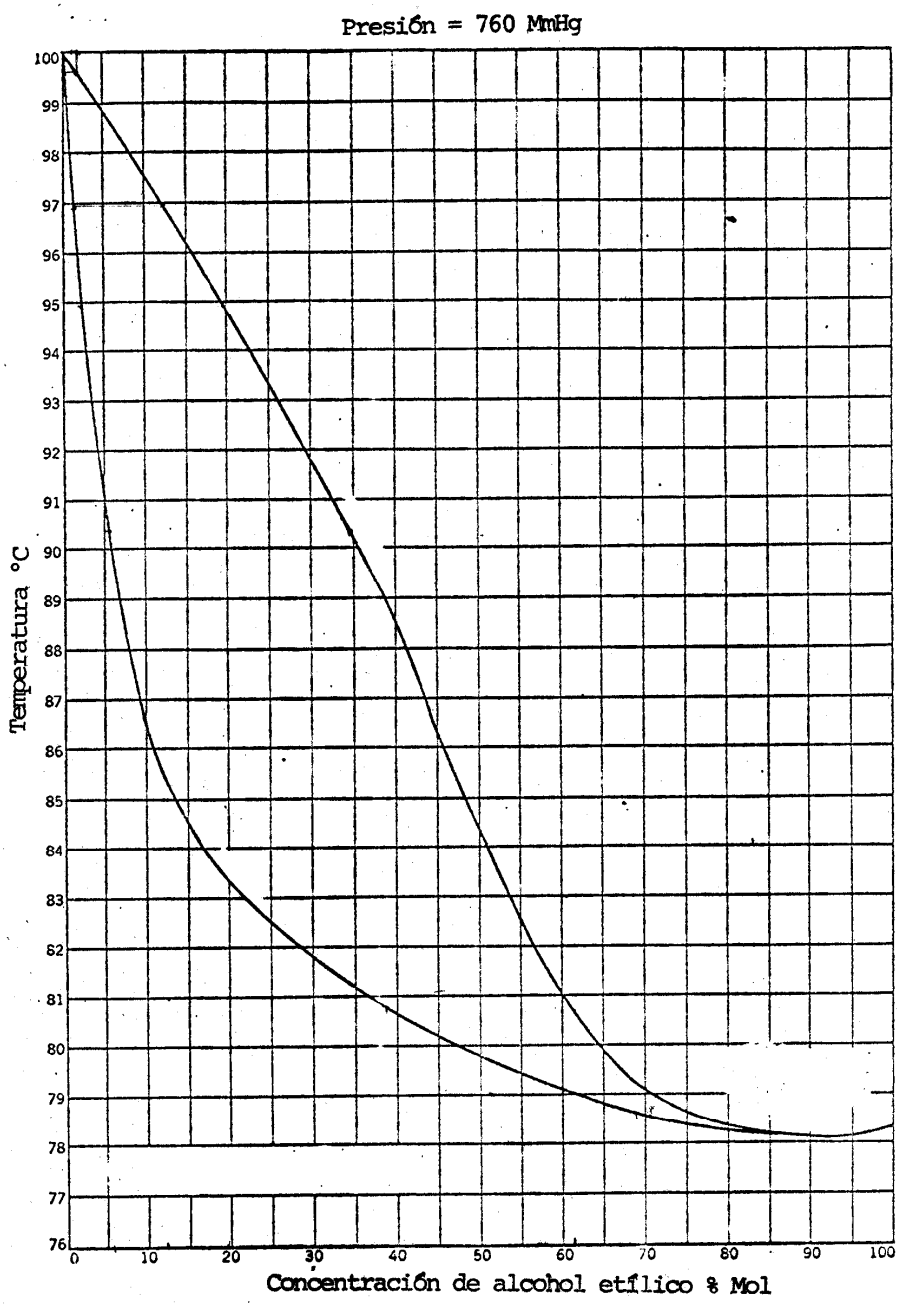


Temp. °C	Presión de Vapor
78.3	1.000
80.0	1.069
90.0	1.562
100.0	2.228
110.0	3.107
120.0	4.243
130.0	5.685
140.0	7.486
150.0	9.700
160.0	12.390
170.0	15.610
180.0	19.440
190.0	23.940
200.0	29.200
210.0	35.310
220.0	42.380
230.0	50.530
240.0	59.920
243.1	63.110

5.13.- DATOS DE EQUILIBRIO VAPOR-LIQUIDO EN SOLUCIONES DE ALCOHOL ETILICO Y AGUA

Composición de Vapor		Comp. de líquido	Comp. de vapor
% Mol Alcohol Etílico		%Mol Alcohol Etílico	% Peso Alcohol Etílico
Presión= 730-750 MmHg	Presión = 760 MmHg	%Peso Alcohol Etílico	Presión=730-750
10.4	—	1.0	10.3
19.0	—	2.0	19.2
25.0	—	3.0	26.3
29.7	28.70	4.0	32.5
33.2	—	5.0	37.7
36.4	35.60	6.0	41.9
41.0	40.65	8.0	48.1
44.2	42.38	10.0	52.7
46.8	46.30	12.0	56.5
48.8	48.75	14.0	59.5
50.5	50.40	16.0	61.9
51.9	51.75	18.0	63.9
53.1	52.85	20.0	65.6
54.1	53.90	22.0	67.2
55.1	54.85	24.0	68.4
56.0	55.70	26.0	69.4
56.8	56.50	28.0	70.4
57.6	57.52	30.0	71.3
58.4	58.05	32.0	72.0
59.1	58.85	34.0	72.8
59.9	59.65	36.0	73.4
60.7	60.45	38.0	74.0
61.4	61.25	40.0	74.6
62.1	62.00	42.0	75.1
62.9	62.80	44.0	75.6
63.7	63.65	46.0	76.1
64.6	64.40	48.0	76.6
65.4	65.20	50.0	77.1
66.3	66.00	52.0	77.5
67.2	66.90	54.0	78.0
68.1	67.75	56.0	78.4
69.0	68.70	58.0	78.9
69.9	69.65	60.0	79.4
70.9	70.65	62.0	79.9
71.9	71.75	64.0	80.5
73.0	72.90	66.0	81.1
74.1	74.10	68.0	81.7
75.3	75.25	70.0	82.2
76.5	76.50	72.0	82.9
77.7	77.75	74.0	83.6
79.0	79.05†	76.0	84.3
80.4	80.40†	78.0	85.0
81.8	81.75†	80.0	85.8
83.3	83.20†	82.0	86.8
84.8	84.70†	84.0	87.7
86.4	86.40†	86.0	88.8
88.1	88.20†	88.0	90.0
—	89.43*	89.43 mole %	—
89.8	—	90.0	91.2
91.7	—	92.0	92.6
93.6	—	94.0	94.2
95.6	—	96.0	95.9
97.8	—	98.0	97.8
100.0	—	100.0	100.0

5.14.- DIAGRAMA DE TEMPERATURA-COMPOSICION PARA SOLUCIONES DE ALCOHOL ETILICO Y AGUA



5.15.- ENTALPIA (CONTENIDO TOTAL DE CALOR) EN SOLUCIONES DE ALCOHOL ETILICO Y AGUA.

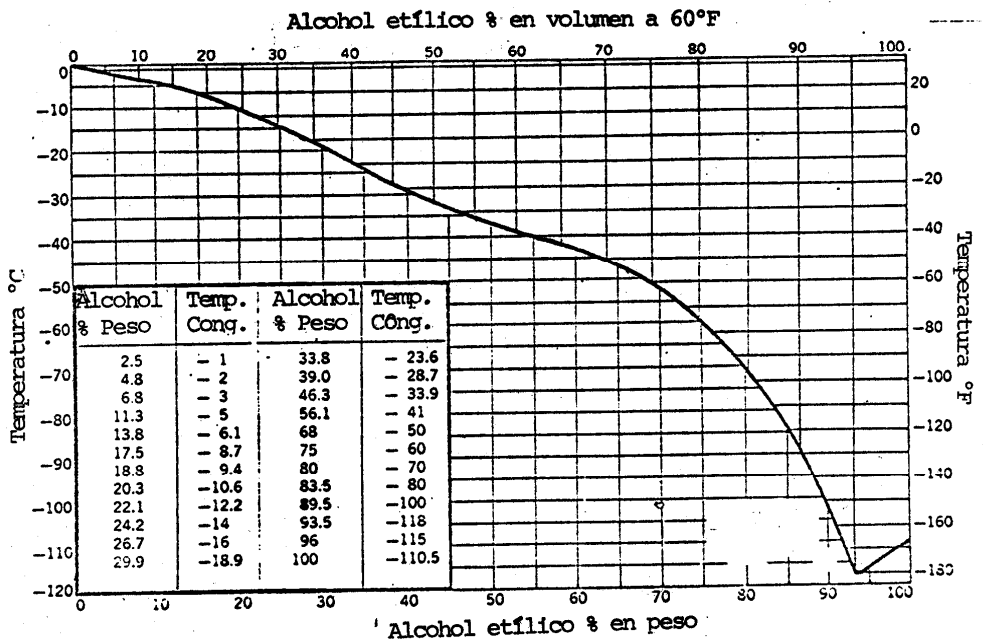
Soluciones líquidas

Alcohol Etílico % Peso	Entalpia BTU/lb a: 200°F	190°F	180°F	170°F	160°F	150°F	140°F
0	167.5	158.0	148.0	137.5	128.0	118.0	107.5
10		151.0	140.0	130.0	119.5	109.0	98.5
20			134.5	124.5	114.0	103.5	92.5
30			131.0	121.0	110.0	99.5	88.5
40				118.0	107.5	97.0	86.5
50				114.5	104.0	94.0	84.0
60				110.0	99.5	90.0	81.0
70				105.0	95.5	86.5	77.5
80				99.5	90.5	82.0	73.5
90				93.0	84.5	76.5	69.0
100				86.0	78.0	71.5	64.5
	130°F	120°F	110°F	100°F	90°F	80°F	70°F
0	98.0	88.0	78.0	68.0	58.0	47.5	37.5
10	88.0	78.5	67.8	57.0	47.8	37.5	27.0
20	81.5	71.0	61.0	50.5	40.5	30.0	19.5
30	78.0	66.6	57.0	47.0	37.0	26.5	16.5
40	76.5	66.2	56.0	45.8	36.0	26.8	16.7
50	74.5	64.7	55.0	45.0	35.8	27.0	18.0
60	71.5	62.7	54.0	44.5	35.6	27.5	19.0
70	69.0	60.5	52.0	43.8	35.5	28.0	20.0
80	65.5	57.5	49.2	42.5	35.0	27.5	20.2
90	61.5	54.5	47.0	40.5	33.8	27.0	20.5
100	58.0	51.5	44.8	39.0	33.0	26.8	21.0
	60°F	50°F	40°F	32°F	20°F	10°F	0°F
0	28.0	18.0	8.0	0.0			
10	16.5	6.5	−3.9	−12.3			
20	9.2	−1.2	−11.5	−19.8	−32.0		
30	6.8	−3.9	−14.4	−21.7	−33.5	−43.5	−53.5
40	7.1	−2.3	−12.5	−19.5	−30.5	−40.0	−49.2
50	8.7	0.0	−9.5	−16.0	−26.0	−34.5	−42.5
60	10.5	2.0	−6.0	−12.4	−21.5	−29.4	−36.0
70	12.0	4.3	−3.0	−9.4	−18.0	−24.8	−31.5
80	13.0	6.0	−0.9	−6.5	−14.0	−20.5	−26.5
90	14.0	7.7	1.4	−3.5	−10.5	−16.5	−22.2
100	15.4	9.7	4.5	0.2	−6.5	−11.7	−17.0

Soluciones en ebullición

Alcohol Etílico % Peso	Temp Ebul	Entalpia BTU/lb Líq. Sat.	Vapor Sat.
0	100.0	180.1	1150.0
5	95.2	169.3	1115.0
10	91.8	159.8	1082.0
15	89.2	151.2	1047.5
20	87.3	144.3	1012.5
25	85.6	139.3	977.5
30	84.7	135.0	943.0
35	83.9	131.3	908.0
40	83.4	128.2	873.0
45	82.7	125.3	839.0
50	82.2	122.9	804.0
55	81.8	120.3	768.0
60	81.0	117.5	734.0
65	80.4	114.3	700.0
70	79.9	111.1	664.0
75	79.5	107.5	630.0
80	79.0	103.8	596.0
85	78.6	100.3	560.0
90	78.3	96.6	526.0
95	78.2	92.7	490.1
100	78.3	89.0	457.5

5.16.- PUNTOS DE ROCIO EN MEZCLAS DE ALCOHOL ETILICO Y AGUA



Alcohol % Peso	Temp. Cong.	Alcohol % Peso	Temp. Cong.
2.5	– 1	33.8	– 23.6
4.8	– 2	39.0	– 28.7
6.8	– 3	46.3	– 33.9
11.3	– 5	56.1	– 41
13.8	– 6.1	68	– 50
17.5	– 8.7	75	– 60
18.8	– 9.4	80	– 70
20.3	–10.6	83.5	– 80
22.1	–12.2	89.5	–100
24.2	–14	93.5	–118
26.7	–16	96	–115
29.9	–18.9	100	–110.5