Humidity Conversion

By R.L. Snyder (Revised March 24, 2005)

This Web page provides the equations used to make humidity conversions and tables of saturation vapor pressure. For a pdf file of this document, click on HumCon.pdf. The saturation vapor pressure tables in an MS Excel spreadsheet can be downloaded by clicking on es.xls.

Barometric Pressure

Barometric pressure (P) in kPa from elevation (E_L) in m above sea level was reported by Jensen, Burman and Allen, 1990 as

$$P = 101.3\left[\frac{293 - 0.0065E_L}{293}\right]^{5.26} \quad (1)$$

Latent heat of vaporization

Latent heat of vaporization (λ) in kJ kg^{-1} from air temperature (T) in ^{o}C

$$\lambda = 2501 - 2.361T \quad (2)$$

Saturation Vapor Pressure

Saturation vapor pressure over water is the vapor pressure of the air when the number of water molecules condensing equals the number evaporating from a flat surface of water with both the air and water at some temperature (T). An equation for the saturation vapor pressure (e_s) over water at temperature (T) in ^{o}C was given by Tetens (1930) as

$$e_s = 0.6108\exp\left[\frac{17.27T}{T + 237.3}\right] \quad (3)$$

Values of e_s for T = -14.9 to 0 and for T = 0 to 49.9 are given in Tables 1 and 2.

When the number of water molecules sublimating equals the number depositing onto a flat surface of ice with both the air and ice at some temperature (T), the saturation vapor pressure (e_s) in kPa over ice at temperature (T) in ^{o}C was given by Tetens (1930) as

$$e_s = 0.6108 \exp\left[\frac{21.875T}{T+265.5}\right] \quad (4)$$

Values of e_s for T = 0 to -14.9 are given in Table 3.

Dew point and Ice point Temperature

Dew-point temperature (T_d) in ^{o}C from air temperature (T) in ^{o}C and relative humidity (RH) in %

$$T_d = \frac{237.3\left(\frac{\ln(RH/100)}{17.27} + \frac{T}{237.3+T}\right)}{1-\left(\frac{\ln(RH/100)}{17.27} + \frac{T}{237.3+T}\right)} \quad (5)$$

Ice-point temperature (T_i) in ^{o}C from air temperature (T) in ^{o}C and relative humidity (RH) in %

$$T_i = \frac{265.5\left(\frac{\ln(RH/100)}{21.875} + \frac{T}{265.5+T}\right)}{1-\left(\frac{\ln(RH/100)}{21.875} + \frac{T}{265.5+T}\right)} \quad (6)$$

Note that the actual vapor pressure (e) is equal to the saturation vapor pressure (e_d) at the dew-point temperature (T_d) and, for subzero temperatures, e equals the saturation vapor pressure (e_i) at the ice point temperature (T_i).

Dew-point temperature (T_d) in ^{o}C from vapor pressure ($e = e_d$) in kPa over water is calculated in two steps

$$b = \frac{\ln(e/0.6108)}{17.27} \quad (7)$$

$$T_d = 237.3\left(\frac{b}{1-b}\right) \quad (8)$$

Ice-point temperature (T_i) in ^{o}C from vapour pressure ($e = e_i$) in kPa over ice is calculated in two steps

$$b_i = \frac{\ln(e/0.6108)}{21.875} \quad (9)$$

$$T_i = 265.5\left(\frac{b}{1-b}\right) \quad (10)$$

Psychrometric Constant

Psychrometric constant (γ) in kPa $^{o}C^{-1}$ for liquid water as a function of barometric pressure (P) in kPa and wet-bulb temperature (T_w) in ^{o}C was given by Fritschen and Gay (1979) as

$$\gamma = 0.000660\left(1 + 0.00115T_w\right)P \quad (11)$$

Psychrometric constant (γ') in kPa $^{o}C^{-1}$ for ice as a function of barometric pressure (P) in kPa and frost-bulb temperature (T_f) in ^{o}C is

$$\gamma' = 0.000582\left(1 + 0.00115T_f\right)P \quad (12)$$

Vapor Pressure

Vapor pressure ($e = e_d$) in kPa at the dew point temperature (T_d) in ^{o}C

$$e_d = 0.6108\exp\left[\frac{17.27T_d}{T_d + 237.3}\right] \quad (13)$$

Vapor pressure ($e = e_i$) in kPa at the subzero ice point temperature (T_i) in ^{o}C

$$e_i = 0.6108\exp\left[\frac{21.875T_i}{T_i + 265.5}\right] \quad (14)$$

Vapor pressure (e) in kPa from dry (T) and wet-bulb (T_w) temperature in °C and barometric pressure (P) and kPa

$$e = e_w - \gamma\left(T - T_w\right) = e_w - 0.000660\left(1 + 0.00115T_w\right)\left(T - T_w\right)P \quad (15)$$

where e_w in kPa is the saturation vapor pressure at the wet-bulb temperature (T_w) in ^{o}C. It is calculated by substituting T_w for T in Equation 4.

Vapor pressure (e) in kPa from dry (T) and frost-bulb (T_f) temperature in °C and barometric pressure (P) in kPa

$$e = e_i - \gamma'\left(T - T_f\right) = e_f - 0.000582\left(1 + 0.00115T_f\right)\left(T - T_f\right)P \quad (16)$$

where e_f is the saturation vapor pressure at the frost-bulb temperature. It is calculated by substituting T_f in ^{o}C for T in Equation 4.

Slope of Saturation Vapor Pressure

Slope of Saturation Vapor Pressure (Δ) in kPa $^{o}C^{-1}$ over liquid water with saturation vapor pressure (e_s) in kPa at temperature T in ^{o}C

$$\Delta = \frac{4098 e_s}{(T + 237.3)^2} \quad (17)$$

Equivalent Temperature

Equivalent temperature (T_e) in ^oC from temperature T in ^oC, vapor pressure e in kPa and the psychrometric constant γ in kPa $^oC^{-1}$

$$T_e = T + \frac{e}{\gamma} \quad (18)$$

Absolute Humidity

Absolute humidity (χ) in g m^{-3} from vapor pressure (e) in kPa and temperature (T) in ^oC

$$\chi = \frac{2165\, e}{T + 273.16} \quad (19)$$

Table 1. Saturation vapor pressure (e_s) in kPa over a flat surface of liquid water calculated using Tetens' formula (Equation 4) for temperature between 0.0 °C and -14.9 °C.

	Temperature (°C)									
	-0.0	-0.1	-0.2	-0.3	-0.4	-0.5	-0.6	-0.7	-0.8	-0.9
-14	0.207	0.205	0.203	0.202	0.200	0.199	0.197	0.195	0.194	0.192
-13	0.224	0.223	0.221	0.219	0.217	0.216	0.214	0.212	0.210	0.209
-12	0.243	0.241	0.240	0.238	0.236	0.234	0.232	0.230	0.228	0.226
-11	0.264	0.262	0.260	0.258	0.256	0.253	0.251	0.249	0.247	0.245
-10	0.286	0.283	0.281	0.279	0.277	0.275	0.272	0.270	0.268	0.266
-9	0.309	0.307	0.304	0.302	0.300	0.297	0.295	0.293	0.290	0.288
-8	0.334	0.332	0.329	0.327	0.324	0.322	0.319	0.317	0.314	0.312
-7	0.361	0.359	0.356	0.353	0.350	0.348	0.345	0.342	0.340	0.337
-6	0.390	0.387	0.384	0.381	0.378	0.376	0.373	0.370	0.367	0.364
-5	0.421	0.418	0.415	0.412	0.409	0.405	0.402	0.399	0.396	0.393
-4	0.454	0.451	0.447	0.444	0.441	0.437	0.434	0.431	0.428	0.424
-3	0.490	0.486	0.482	0.479	0.475	0.472	0.468	0.465	0.461	0.458
-2	0.527	0.524	0.520	0.516	0.512	0.508	0.504	0.501	0.497	0.493
-1	0.568	0.564	0.559	0.555	0.551	0.547	0.543	0.539	0.535	0.531
-0	0.611	0.606	0.602	0.598	0.593	0.589	0.585	0.580	0.576	0.572

Table 2. Saturation vapor pressure (kPa) over a flat surface of liquid water calculated using Tetens' formula (Equation 4) for temperature between 0 °C and 49.9 °C.

	Temperature (°C)									
	0.0	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9
0	0.611	0.615	0.620	0.624	0.629	0.633	0.638	0.643	0.647	0.652
1	0.657	0.661	0.666	0.671	0.676	0.681	0.686	0.691	0.696	0.701
2	0.706	0.711	0.716	0.721	0.726	0.731	0.737	0.742	0.747	0.752
3	0.758	0.763	0.769	0.774	0.780	0.785	0.791	0.796	0.802	0.808
4	0.813	0.819	0.825	0.831	0.836	0.842	0.848	0.854	0.860	0.866
5	0.872	0.878	0.885	0.891	0.897	0.903	0.910	0.916	0.922	0.929
6	0.935	0.942	0.948	0.955	0.961	0.968	0.975	0.981	0.988	0.995
7	1.002	1.009	1.016	1.023	1.030	1.037	1.044	1.051	1.058	1.065
8	1.073	1.080	1.087	1.095	1.102	1.110	1.117	1.125	1.133	1.140
9	1.148	1.156	1.164	1.172	1.179	1.187	1.195	1.203	1.212	1.220
10	1.228	1.236	1.245	1.253	1.261	1.270	1.278	1.287	1.295	1.304
11	1.313	1.321	1.330	1.339	1.348	1.357	1.366	1.375	1.384	1.393
12	1.403	1.412	1.421	1.431	1.440	1.449	1.459	1.469	1.478	1.488
13	1.498	1.508	1.517	1.527	1.537	1.547	1.558	1.568	1.578	1.588
14	1.599	1.609	1.619	1.630	1.641	1.651	1.662	1.673	1.684	1.694
15	1.705	1.716	1.727	1.739	1.750	1.761	1.772	1.784	1.795	1.807
16	1.818	1.830	1.842	1.853	1.865	1.877	1.889	1.901	1.913	1.925
17	1.938	1.950	1.962	1.975	1.987	2.000	2.013	2.025	2.038	2.051
18	2.064	2.077	2.090	2.103	2.116	2.130	2.143	2.157	2.170	2.184
19	2.197	2.211	2.225	2.239	2.253	2.267	2.281	2.295	2.309	2.324
20	2.338	2.353	2.367	2.382	2.397	2.412	2.427	2.442	2.457	2.472
21	2.487	2.502	2.518	2.533	2.549	2.564	2.580	2.596	2.612	2.628
22	2.644	2.660	2.676	2.693	2.709	2.726	2.742	2.759	2.776	2.792
23	2.809	2.826	2.844	2.861	2.878	2.896	2.913	2.931	2.948	2.966
24	2.984	3.002	3.020	3.038	3.056	3.075	3.093	3.112	3.130	3.149
25	3.168	3.187	3.206	3.225	3.244	3.263	3.283	3.302	3.322	3.342
26	3.361	3.381	3.401	3.422	3.442	3.462	3.483	3.503	3.524	3.544
27	3.565	3.586	3.607	3.629	3.650	3.671	3.693	3.714	3.736	3.758
28	3.780	3.802	3.824	3.846	3.869	3.891	3.914	3.937	3.960	3.983
29	4.006	4.029	4.052	4.076	4.099	4.123	4.147	4.171	4.195	4.219
30	4.243	4.267	4.292	4.317	4.341	4.366	4.391	4.416	4.442	4.467
31	4.493	4.518	4.544	4.570	4.596	4.622	4.648	4.675	4.701	4.728
32	4.755	4.782	4.809	4.836	4.863	4.891	4.918	4.946	4.974	5.002
33	5.030	5.058	5.087	5.115	5.144	5.173	5.202	5.231	5.260	5.290
34	5.319	5.349	5.379	5.409	5.439	5.469	5.500	5.530	5.561	5.592
35	5.623	5.654	5.685	5.717	5.748	5.780	5.812	5.844	5.876	5.908
36	5.941	5.974	6.007	6.039	6.073	6.106	6.139	6.173	6.207	6.241
37	6.275	6.309	6.343	6.378	6.413	6.448	6.483	6.518	6.553	6.589
38	6.625	6.661	6.697	6.733	6.769	6.806	6.843	6.880	6.917	6.954
39	6.991	7.029	7.067	7.105	7.143	7.181	7.220	7.258	7.297	7.336
40	7.376	7.415	7.455	7.494	7.534	7.574	7.615	7.655	7.696	7.737
41	7.778	7.819	7.861	7.902	7.944	7.986	8.028	8.071	8.113	8.156

42	8.199	8.242	8.285	8.329	8.373	8.417	8.461	8.505	8.550	8.595
43	8.640	8.685	8.730	8.776	8.821	8.867	8.914	8.960	9.007	9.053
44	9.101	9.148	9.195	9.243	9.291	9.339	9.387	9.436	9.484	9.533
45	9.582	9.632	9.681	9.731	9.781	9.832	9.882	9.933	9.984	10.035
46	10.086	10.138	10.190	10.242	10.294	10.347	10.399	10.452	10.506	10.559
47	10.613	10.667	10.721	10.775	10.830	10.885	10.940	10.995	11.051	11.107
48	11.163	11.219	11.276	11.333	11.390	11.447	11.504	11.562	11.620	11.679
49	11.737	11.796	11.855	11.914	11.974	12.034	12.094	12.154	12.215	12.276

Table 3. Saturation vapor pressure (kPa) over a flat surface of ice calculated using Tetens' formula (Equation 5) for temperature between 0.0 °C and -14.9 °C.

	Temperature (°C)									
	0.0	-0.1	-0.2	-0.3	-0.4	-0.5	-0.6	-0.7	-0.8	-0.9
-14	0.181	0.179	0.177	0.176	0.174	0.173	0.171	0.169	0.168	0.166
-13	0.198	0.196	0.194	0.193	0.191	0.189	0.187	0.186	0.184	0.182
-12	0.217	0.215	0.213	0.211	0.209	0.207	0.205	0.204	0.202	0.200
-11	0.237	0.235	0.233	0.231	0.229	0.227	0.225	0.223	0.221	0.219
-10	0.259	0.257	0.255	0.253	0.250	0.248	0.246	0.244	0.242	0.239
-9	0.284	0.281	0.279	0.276	0.274	0.271	0.269	0.266	0.264	0.262
-8	0.310	0.307	0.304	0.302	0.299	0.296	0.294	0.291	0.289	0.286
-7	0.338	0.335	0.332	0.329	0.326	0.323	0.321	0.318	0.315	0.312
-6	0.368	0.365	0.362	0.359	0.356	0.353	0.350	0.347	0.344	0.341
-5	0.401	0.398	0.395	0.391	0.388	0.385	0.381	0.378	0.375	0.372
-4	0.437	0.433	0.430	0.426	0.422	0.419	0.415	0.412	0.408	0.405
-3	0.476	0.472	0.468	0.464	0.460	0.456	0.452	0.448	0.445	0.441
-2	0.517	0.513	0.509	0.505	0.500	0.496	0.492	0.488	0.484	0.480
-1	0.562	0.558	0.553	0.548	0.544	0.539	0.535	0.530	0.526	0.522
0	0.611	0.606	0.601	0.596	0.591	0.586	0.581	0.576	0.572	0.567

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