

Carbonation is the dissolving of gaseous carbon dioxide (CO<sub>2</sub>) in an aqueous solution (in this case, beer.) Carbonation is governed by Henry's Law, which states: "At a constant temperature, the amount of a given gas that dissolves in a given type and volume of liquid is directly proportional to the partial pressure of that gas in equilibrium with that liquid." Or, in other words, the solubility of a gas in a liquid is directly proportional to the partial pressure of the gas above the liquid.

This is the science behind natural carbonation. As the pressure above the beer increases (in a bottle, cask or tank) some of the CO<sub>2</sub> is dissolved into beer.

Carbonating a full batch of beer with a carbonating stone in a brite tank provides for much quicker carbonation. The carbonating stone increases the surface area contact with the beer by producing tiny bubbles of CO<sub>2</sub>, which are more easily absorbed into the beer.

Before carbonating your beer, it is important to know the temperature of your beer and your target carbonation level.

The lower the temperature of the beer, the more easily CO<sub>2</sub> is dissolved into the beer. Ideally, you want your beer between 30 and 32 degrees Fahrenheit, although it should not be an issue if your beer temperature is as high as 38 or 40F.

The carbonation level – or amount of CO<sub>2</sub> in solution – of beer is most often expressed in terms of "volumes of CO<sub>2</sub>." This is a measure of the volume or "space" the gas would occupy at atmospheric pressure and 0 degrees Celsius if it were removed from the beer. For instance, if all of the CO<sub>2</sub> were removed from one liter of a typical American ale at 2.5 volumes and expanded at 0 C, its volume would be 2.5 liters.

Different styles of beer are carbonated to different levels, and draft beer is typically packaged with lower carbonation levels than bottled beer. Once you know the temperature of your beer and your target carbonation level, you can download a carbonation chart like the one on the last page of this document.

This chart will give you a rough idea of the pressure required to achieve the desired volumes of CO<sub>2</sub> at a given temperature at equilibrium. Find the temperature of your beer on the left axis of the chart and then read across until you find the desired volumes of CO<sub>2</sub>, then follow the column up to see at what pressure that level of carbonation is achieved\*. You will know your beer is at equilibrium when the head pressure (as measured by the pressure gauge on the tank) is equal to the pressure being added via the carbonation stone and no more gas is dissolving into the beer.

Before carbonating your first batch, you need to know the "wetting pressure" of your carbonation stone. This is the amount of pressure required for CO<sub>2</sub> to push through the pores of the stone and begin making tiny bubbles. Each stone will have a different wetting pressure. To determine your wetting pressure, attach CO<sub>2</sub> to the stone and put it in a bucket of water or sanitizer. Set it in sideways, as that is the orientation it will be in when carbonating your beer. Turn the pressure up slowly until a nice curtain of bubbles rises. Record that pressure. That is your wetting pressure. It is usually somewhere between 2-8 psi.

There is also hydrostatic pressure exerted on the stone by the beer in the tank. Every 28 inches of liquid exert 1 pound of pressure on the stone. So, measure from your carbonation stone to the liquid level on your sight glass to get the hydrostatic pressure.

Chances are you are starting with completely flat beer. The first step is to get it into the brite tank and make sure it is chilled. If you had already chilled the beer in the fermenter, simply transfer the beer to the brite (making sure you first purge the tank with CO<sub>2</sub>). If your beer is not chilled, make sure it is chilled before you begin carbonating. If you filter your beer, you normally do that as you transfer the chilled beer from the fermenter into the brite tank.

Let's say you are brewing a standard American ale (pale, IPA, porter, etc.) and you want about 2.5 volumes of CO<sub>2</sub> in the beer. Check the temperature of your beer (if you have no thermowell in the brite tank, draw off a small sample from the sample port and check the temperature). From your carbonation chart, the vertical axis is your temperature. Find the temperature of your beer, then run across horizontally until you find your desired volumes of CO<sub>2</sub>. For example, at 35 degrees F 2.52 volumes are achieved at 10 psi. So, when the head pressure, as measured by the pressure gauge on top of the tank reaches equilibrium at 10 psi, your beer should be carbonated to 2.52 volumes of CO<sub>2</sub>. To reach that level, you want to go slowly, otherwise you run the risk of CO<sub>2</sub> "scrubbing", which reduces your head retention and blows off a lot of your volatile aroma components.

One method for knowing when your tank has reached equilibrium is to install a rotometer – or inline gas flow meter – between your regulator and your carbonation stone. When the flow through the stone stops or slows to a very slow trickle, your tank should be at or near equilibrium.

There are several methods used for reaching that pressure. We will focus on two:

- Starting with 0 head pressure and slowly building to your target pressure; and
- Starting with head pressure of 1 psi below your target saturation pressure.

With both methods, it can be desirable to start with your carbonation stone pressure slightly higher than the head pressure and slowly bleed off some gas from the top of the tank. This can scrub any dissolved air that made its way into the beer during transfer to the brite tank. Be careful not to overdo this or it can lead to foaming in the tank, which will scrub desirable aroma components and adversely affect head retention.

In the first method, you start by setting your regulator on the carbonation stone line at about 2-3 psi over your wetting pressure. This will also account for the liquid pressure on the stone. Start with a very low psi and gradually increase the pressure every half-hour to hour until you reach your final pressure, which would be the sum of the wetting pressure + liquid pressure + target pressure.

For example, if to reach your target volumes of CO<sub>2</sub>, the chart says you need 10 psi and you know your wetting pressure is 3 and you have 53 inches of beer in your tank (about 2 pounds of pressure), your final pressure through the stone would be  $10+3+2=15$  psi. Once you reach 15 psi, start watching your pressure gauge. When it stabilizes at 10 psi, you should have beer carbonated to 2.52 volumes of CO<sub>2</sub>. This can take anywhere from hours to more than a day, depending on the temperature of your beer and any residual carbonation left from fermentation.

The rationale for starting with 0 head pressure is that you can start with a lower pressure through your carbonation stone and avoid any foaming, which would scrub aromatics and damage head retention.

In the second method, you would put head pressure of 14 psi on the brite beer tank (after the initial venting) and set your stone pressure to 15 psi (10 psi target saturation pressure + wetting pressure + liquid pressure). Once the head pressure ticks upward to 15 psi and reaches equilibrium, your beer is carbonated. The trick here is knowing when the gases have reached equilibrium, not just equal pressure. This is where your rotometer, as well as testing with a carbonation tester or taste-testing becomes important.

The rationale for putting head pressure on top of the beer is that CO<sub>2</sub> bubbling up through the beer will be forced into solution faster by the head pressure. It also precludes the need for the CO<sub>2</sub> to go into solution and then come out of solution to fill the head space.

One method for knowing when your tank has reached equilibrium is to install a rotometer – or inline gas flow meter – between your regulator and your carbonation stone. When the flow through the stone stops or slows to a very slow trickle, your tank should be at or near equilibrium.

Whichever method you use, it is desirable leave the fully carbonated beer in the tank a couple of days, or at least overnight, to allow the CO<sub>2</sub> to “bind” to the beer. This will improve head retention.

The numbers on the chart are not exact, however, because the values in the chart are based on beer with a specific gravity of 1.015, an alcohol content of not more than 4.8 by volume and an elevation of sea level. For instance, for every 2,000 feet above sea level, it requires one extra pound of pressure to reach the desired carbonation level.

To know the exact carbonation level of your beer, you will need to use a carbonation tester such as a Zahm and Nagel Series 1000 CO<sub>2</sub> Volume Meter or a Taprite Carbonation tester. If you don't have such a device, use the chart to get close to your target, then taste your beer to assess whether it is carbonated to your satisfaction. When sampling beer from the brite tank, it is best to use a long (e.g., 8' to 10') 3/16" draft beer line to keep the beer from gushing out and immediately de-carbonating itself.



**Typical CO<sub>2</sub> Saturation by Style (in volumes)**

<b>English Ales</b>	1.5 - 2.0	<b>European Lagers</b>	2.2 - 2.7
<b>Stout/Porter</b>	1.7 - 2.3	<b>American Ales/Lagers</b>	2.2 - 2.7
<b>Belgian Ales</b>	1.9 - 2.4	<b>Lambic</b>	2.4 - 2.8
<b>Wheat Beer</b>	3.3 - 4.5	<b>Fruit Lambic</b>	3.0 - 4.5

**Pressure (PSI)**

*Reestrogulae Sings*

(°F)	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30
30	1.82	1.92	2.03	2.14	2.23	2.36	2.48	2.60	2.70	2.82	2.93	3.02	3.13	3.24	3.35	3.46	3.57	3.67	3.78	3.89	4.00	4.11	4.22	4.33	4.44	4.55	4.66	4.77	4.87	4.98
31	1.78	1.88	2.00	2.10	2.20	2.31	2.42	2.54	2.65	2.76	2.86	2.96	3.07	3.17	3.28	3.39	3.50	3.60	3.71	3.82	3.93	4.03	4.14	4.25	4.35	4.46	4.57	4.68	4.78	4.89
32	1.75	1.85	1.95	2.05	2.15	2.27	2.38	2.48	2.59	2.70	2.80	2.90	3.00	3.11	3.21	3.31	3.42	3.52	3.63	3.73	3.84	3.94	4.04	4.15	4.25	4.36	4.46	4.57	4.67	4.77
33	1.71	1.81	1.91	2.01	2.10	2.23	2.33	2.43	2.53	2.63	2.74	2.84	2.96	3.06	3.15	3.25	3.35	3.46	3.56	3.66	3.76	3.87	3.97	4.07	4.18	4.28	4.38	4.48	4.59	4.69
34	1.68	1.78	1.86	1.97	2.06	2.18	2.28	2.38	2.48	2.58	2.69	2.79	2.90	3.00	3.09	3.19	3.29	3.39	3.49	3.59	3.69	3.79	3.90	4.00	4.10	4.20	4.30	4.40	4.50	4.60
35	1.63	1.73	1.83	1.93	2.02	2.14	2.24	2.34	2.43	2.52	2.63	2.73	2.83	2.93	3.02	3.12	3.22	3.32	3.42	3.52	3.62	3.72	3.82	3.92	4.01	4.11	4.21	4.31	4.41	4.51
36	1.60	1.69	1.79	1.88	1.98	2.09	2.19	2.29	2.38	2.47	2.57	2.67	2.77	2.86	2.96	3.05	3.15	3.24	3.34	3.43	3.53	3.63	3.72	3.82	3.92	4.01	4.11	4.21	4.30	4.40
37	1.55	1.65	1.74	1.84	1.94	2.04	2.14	2.24	2.33	2.42	2.52	2.62	2.71	2.80	2.90	3.00	3.09	3.18	3.27	3.37	3.46	3.56	3.65	3.75	3.84	3.94	4.03	4.13	4.22	4.32
38	1.52	1.61	1.71	1.80	1.90	2.00	2.10	2.20	2.29	2.38	2.48	2.57	2.66	2.75	2.85	2.94	3.03	3.12	3.21	3.30	3.40	3.49	3.59	3.68	3.77	3.87	3.96	4.06	4.15	4.24
39	1.49	1.58	1.67	1.77	1.86	1.96	2.06	2.15	2.25	2.34	2.43	2.52	2.61	2.70	2.80	2.89	2.98	3.07	3.16	3.25	3.34	3.44	3.53	3.62	3.71	3.81	3.90	3.99	4.08	4.18
40	1.47	1.56	1.65	1.74	1.83	1.92	2.01	2.10	2.20	2.30	2.39	2.47	2.56	2.65	2.75	2.84	2.93	3.01	3.10	3.19	3.28	3.37	3.46	3.55	3.64	3.73	3.82	3.91	4.01	4.10
41	1.43	1.52	1.61	1.70	1.79	1.88	1.97	2.06	2.16	2.25	2.34	2.43	2.52	2.60	2.70	2.79	2.88	2.96	3.05	3.14	3.23	3.32	3.41	3.50	3.59	3.68	3.77	3.86	3.95	4.04
42	1.39	1.48	1.57	1.66	1.75	1.85	1.94	2.02	2.12	2.21	2.30	2.39	2.48	2.56	2.65	2.74	2.83	2.91	3.00	3.09	3.18	3.26	3.35	3.44	3.53	3.62	3.70	3.79	3.88	3.97
43	1.37	1.46	1.54	1.63	1.72	1.81	1.90	1.99	2.08	2.17	2.26	2.34	2.43	2.52	2.61	2.69	2.78	2.86	2.95	3.04	3.13	3.21	3.30	3.39	3.47	3.56	3.65	3.74	3.82	3.91
44	1.35	1.43	1.52	1.60	1.69	1.78	1.87	1.95	2.04	2.13	2.22	2.30	2.39	2.47	2.56	2.64	2.73	2.81	2.90	2.99	3.07	3.10	3.24	3.33	3.41	3.50	3.58	3.67	3.76	3.84
45	1.32	1.41	1.49	1.58	1.66	1.75	1.84	1.91	2.00	2.08	2.17	2.26	2.34	2.42	2.51	2.60	2.69	2.77	2.86	2.94	3.02	3.11	3.19	3.28	3.36	3.45	3.53	3.62	3.70	3.79
46	1.28	1.37	1.45	1.54	1.62	1.71	1.80	1.88	1.96	2.04	2.13	2.22	2.30	2.38	2.47	2.55	2.64	2.72	2.81	2.89	2.98	3.06	3.15	3.23	3.31	3.40	3.48	3.57	3.65	3.74
47	1.26	1.34	1.42	1.51	1.59	1.68	1.76	1.84	1.92	2.00	2.09	2.18	2.26	2.34	2.42	2.50	2.59	2.67	2.76	2.84	2.93	3.02	3.09	3.18	3.26	3.35	3.43	3.51	3.60	3.68
48	1.23	1.31	1.39	1.48	1.56	1.65	1.73	1.81	1.89	1.96	2.05	2.14	2.22	2.30	2.38	2.46	2.54	2.62	2.71	2.79	2.88	2.96	3.04	3.13	3.21	3.30	3.38	3.46	3.54	3.63
49	1.21	1.29	1.37	1.45	1.53	1.62	1.70	1.79	1.86	1.93	2.01	2.10	2.18	2.25	2.34	2.42	2.50	2.58	2.67	2.75	2.83	2.91	3.00	3.07	3.15	3.23	3.31	3.39	3.47	3.56
50	1.18	1.26	1.34	1.42	1.50	1.59	1.66	1.74	1.82	1.90	1.98	2.06	2.14	2.21	2.30	2.38	2.46	2.54	2.62	2.70	2.78	2.86	2.94	3.02	3.10	3.17	3.25	3.33	3.41	3.49
51	1.18	1.26	1.34	1.42	1.49	1.57	1.64	1.71	1.79	1.87	1.95	2.02	2.10	2.18	2.26	2.34	2.42	2.49	2.57	2.65	2.74	2.82	2.90	2.97	3.05	3.13	3.19	3.27	3.34	3.42
52	1.16	1.23	1.31	1.39	1.46	1.54	1.61	1.68	1.76	1.84	1.92	1.99	2.06	2.14	2.22	2.30	2.38	2.45	2.53	2.61	2.68	2.76	2.84	2.92	3.00	3.06	3.13	3.22	3.30	3.37
53	1.14	1.21	1.29	1.36	1.44	1.51	1.59	1.66	1.74	1.81	1.89	1.96	2.03	2.10	2.18	2.26	2.34	2.41	2.49	2.57	2.64	2.71	2.79	2.86	2.94	3.01	3.09	3.16	3.24	3.31
54	1.12	1.19	1.27	1.34	1.41	1.49	1.56	1.63	1.71	1.78	1.86	1.93	2.00	2.07	2.15	2.22	2.30	2.37	2.45	2.52	2.59	2.66	2.74	2.81	2.89	2.96	3.04	3.10	3.17	3.24
55	1.10	1.17	1.24	1.31	1.39	1.46	1.53	1.60	1.68	1.75	1.82	1.89	1.97	2.04	2.12	2.18	2.26	2.33	2.40	2.47	2.54	2.62	2.69	2.76	2.83	2.89	2.97	3.04	3.11	3.18
56	1.07	1.15	1.22	1.29	1.36	1.43	1.50	1.57	1.65	1.72	1.79	1.86	1.93	2.00	2.08	2.15	2.22	2.29	2.36	2.43	2.50	2.57	2.64	2.71	2.78	2.85	2.92	2.99	3.06	3.13
57	1.05	1.12	1.19	1.26	1.33	1.40	1.47	1.54	1.62	1.70	1.77	1.83	1.90	1.97	2.04	2.11	2.18	2.25	2.32	2.39	2.46	2.53	2.60	2.66	2.73	2.80	2.87	2.94	3.00	3.08
58	1.03	1.10	1.17	1.24	1.30	1.37	1.44	1.51	1.59	1.67	1.74	1.80	1.87	1.94	2.01	2.08	2.15	2.21	2.28	2.35	2.42	2.48	2.55	2.62	2.69	2.75	2.82	2.88	2.95	3.02
59	1.02	1.09	1.16	1.22	1.29	1.36	1.43	1.49	1.56	1.64	1.71	1.77	1.84	1.91	1.98	2.04	2.11	2.17	2.24	2.31	2.38	2.43	2.50	2.57	2.64	2.70	2.77	2.84	2.91	2.97
60	1.01	1.08	1.15	1.21	1.28	1.34	1.41	1.47	1.54	1.62	1.68	1.75	1.82	1.88	1.95	2.01	2.08	2.14	2.21	2.27	2.34	2.40	2.47	2.53	2.60	2.66	2.73	2.79	2.86	2.92
61	0.99	1.05	1.12	1.18	1.24	1.31	1.37	1.44	1.50	1.57	1.63	1.69	1.76	1.82	1.89	1.95	2.02	2.08	2.14	2.21	2.27	2.34	2.40	2.47	2.53	2.59	2.66	2.72	2.79	2.85
62	0.96	1.02	1.09	1.15	1.21	1.27	1.34	1.40	1.46	1.53	1.59	1.65	1.71	1.78	1.84	1.90	1.97	2.03	2.09	2.15	2.22	2.28	2.34	2.41	2.47	2.53	2.59	2.66	2.72	2.78
63	0.93	0.99	1.06	1.12	1.18	1.24	1.30	1.36	1.42	1.49	1.55	1.61	1.67	1.73	1.79	1.85	1.92	1.98	2.04	2.10	2.16	2.22	2.28	2.35	2.41	2.47	2.53	2.59	2.65	2.71
64	0.91	0.97	1.03	1.09	1.15	1.21	1.27	1.33	1.39	1.45	1.51	1.57	1.63	1.69	1.75	1.81	1.87	1.93	1.99	2.05	2.11	2.17	2.23	2.29	2.35	2.41	2.47	2.52	2.58	2.64
65	0.88	0.94	1.00	1.06	1.11	1.17	1.23	1.29	1.35	1.41	1.46	1.52	1.58	1.64	1.70	1.76	1.82	1.87	1.93	1.99	2.05	2.11	2.17	2.23	2.28	2.34	2.40	2.46	2.52	2.58
66	0.85	0.91	0.97	1.02	1.08	1.14	1.20	1.25	1.31	1.37	1.42	1.48	1.54	1.59	1.65	1.71	1.77	1.82	1.88	1.94	1.99	2.05	2.11	2.16	2.22	2.28	2.34	2.39	2.45	2.51
67	0.83	0.88	0.94	0.99	1.05	1.10	1.16	1.22	1.27	1.33	1.38	1.44	1.49	1.55	1.60	1.66	1.72	1.77	1.83	1.88	1.94	1.99	2.05	2.10	2.16	2.22	2.27	2.33	2.38	2.44
68	0.80	0.85	0.91	0.96	1.02	1.07	1.12	1.18	1.23	1.29	1.34	1.39	1.44	1.50	1.55	1.60	1.66	1.72	1.77	1.83	1.88	1.94	1.99	2.04	2.10	2.15	2.21	2.26	2.32	2.37
69	0.77	0.83	0.88	0.93	0.98	1.04	1.09	1.14	1.19	1.25	1.30	1.35	1.40	1.46	1.51	1.56	1.62	1.67	1.72	1.77	1.83	1.88	1.93	1.98	2.04	2.09	2.14	2.20	2.25	2.30
70	0.75	0.80	0.85	0.90	0.95	1.00	1.05	1.10	1.16	1.21	1.26	1.31	1.36	1.41	1.46	1.51	1.57	1.62	1.67	1.72	1.77	1.82	1.87	1.92	1.98	2.03	2.08	2.13	2.18	2.23