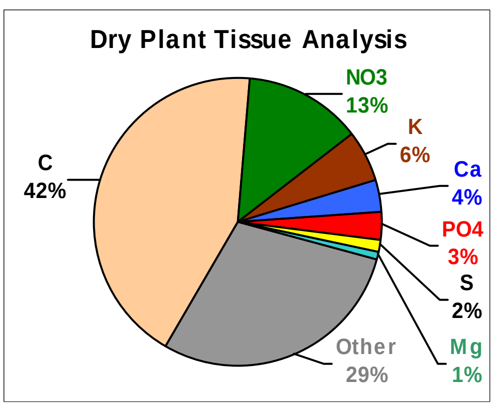
Perpetual Preservation System™
Carbonate Hardness, Potential Hydrogen and Carbon Dioxide. The KH, pH CO2 relationship

Now that we have covered Nitrates, Phosphates, Calcium, Magnesium and General Hardness we must turn to Carbonate Hardness (KH), Carbon Dioxide (CO2) and the level of acidity or alkalinity measured known as Potential Hydrogen or simply as pH (yes small p capital H). A pH value of 7 is considered neutral whereas lower levels are considered acidic and the higher level considered alkaline. There are several test kits available on the market for testing KH and pH so we will not go into the details on the testing aspect of these factors. We will however discuss how to measure CO2 later on as the measure of CO2 is based on the level of KH and pH in the aquarium. Note that the testing of KH is similar to that of testing GH in that the measure of KH is quoted using different measures; it is quoted as either in parts per million (ppm) or German Degrees (^{o}dGH). Note that to convert from ^{o}dGH to ppm the factor is 17.86, accordingly 1 ^{o}dGH equals 17.86 ppm and 2 ^{o}dGH equals 35.72 ppm and so forth. For our purposes we will discuss KH in ^{o}dGH and not using ppm.

Carbonate Hardness (KH)
The first point to express relating to KH is that plants do not need KH for their health however; Carbon is an essential nutrient for plants and is required in large amounts for photosynthesis, approximately 42% Dry Plant Tissue is Carbon (C) and no other element is required to plants in such high quantities as Carbon is.



To supply Carbon to plants we use Carbon Dioxide gas (CO2). CO2 lowers the pH of the water but for certain fish a higher pH is required and this is where KH comes into the equation. Carbonate Hardness, KH, serves as a buffer to the acidic reaction of the CO2 gas so that we may increase or decrease the pH and still allow the desired amount of CO2 to enter the aquarium. We will provide an example of how this functions once we have gone over the basics of all three of the components (KH, pH and CO2) as they must be discussed in their entirety.

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KH may be raised with the addition of certain chemicals the most popular being $NaHCO_3$ your common baking soda, or Calcium Carbonate ($CaCO_3$). Note that the use of baking soda ($NaHCO_3$) is easy to dissolve however it does leave behind traces of Na or sodium which may accumulate after the passage of time if water changes are not performed. The use of CaCo3 takes approximately 24 to 48 hours to dissolve and may be entirely consumed by plants therefore not leaving any other elements behind. As a consequence of raising KH there will be an increase in the pH as well.

Potential Hydrogen (pH)

pH is the measure of Hydrogen ions in the water and the pH value, as noted above, determines whether water is considered acidic (below 7) or alkaline (above 7). The value of the pH is predominantly predetermined by the fish one desires to keep, plus or minus some variation; however, once the desired pH value is known the KH must be adjusted appropriately to allow for the proper amounts of Carbon Dioxide to be dissolved in the water. Again, this relationship will be explored later on.

Carbon Dioxide (CO2)

Research found that CO2 level of 30ppm is adequate for full aquatic plant growth due to the innate inaccuracy of test kits we recommend keeping CO2 levels of approximately 30 to 40 ppm to ensure there is sufficient amount of carbon for plants to consume. CO2 levels above 30 ppm have not shown any additional improvement in plant growth. Presently there are no good test kits to test the level of CO2 in water; however the level of CO2 may be determined using the following equation;

> $3 \times KH \times 10^{(7-pH)}$ (3 times KH times 10 to the power 7 minus pH) we will provide a chart which maps these values given different values of pH and KH for your convenience below.

CO2 may be added to your aquarium using several techniques however there are several articles and posts on the internet that deals with such matters and accordingly will not be discussed here. The addition of CO2 results in a reduction of pH but not KH. This relationship will be demonstrated below. It is important to note that an addition of any element to raise KH or pH will not result in increased CO2 levels. The only manner to increase CO2 is the injection of CO2 in the water.

The KH, pH CO2 relationship

As discussed earlier these three components form a relationship. The following will discuss how this relationship works in practice.

Before we continue we have included a graphical representation of the KH, pH and CO2 relationship that will be used to explain how these three elements are used.

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The KH, pH CO2 relationship

KH / pH	6.00	6.20	6.40	6.60	6.80	7.00	7.20	7.40	7.60	7.80	8.00
1.00	30	19	12	8	5	3	2	1	0.8	0.5	0.3
1.50	45	28	18	11	7	5	3	2	1	0.7	0.5
1.75	53	33	21	13	8	5	3	2	1	0.8	0.5
2.00	60	38	24	15	10	6	4	2	2	1	0.6
2.50	75	47	30	19	12	8	5	3	2	1	0.8
3.00	90	57	36	23	14	9	6	4	2	1	0.9
4.00	120	76	48	30	19	12	8	5	3	2	1
5.00	150	95	60	38	24	15	9	6	4	2	2
6.00	180	114	72	45	29	18	11	7	5	3	2
7.00	210	133	84	53	33	21	13	8	5	3	2
8.00	240	151	96	60	38	24	15	10	6	4	2
9.00	270	170	107	68	43	27	17	11	7	4	3
10.00	300	189	119	75	48	30	19	12	8	5	3

We have already discussed the fact that the ideal range for CO_2 should be within the 30 to 40 ppm range. However from the above chart we see that this range may be achieved at different levels for example: at a pH of 6.0 and a KH of 1
at a pH of 6.6 and a KH of 4
at a pH of 7.0 and a KH of 10
So as you see there exists a change in CO_2 levels whenever there is a change in the KH or pH level. So let us assume that the fish we keep are accustomed to a low pH if the aquarium water has a KH of 1 in order to supply CO_2 at 30ppm we would be forced to drive the pH down to 6.00 which may not be desired. Accordingly we would increase the KH (by either using baking soda or calcium carbonate) which would also result in an increase in the pH. By doing this we have achieved what may be the ideal pH for the fish at 6.2 and the ideal amount of CO_2 for the plants at 30 ppm with a KH of 1.5. To demonstrate this point further assuming we want to keep fish that prefer a neutral pH (a pH of 7) in order to supply 30 ppm of CO_2 we would require a KH of 10. If our tap water contains KH of 1 we would add the required amount of either baking soda or Calcium Carbonate to increase the KH to 10 so that we may be able to provide 30 ppm of CO_2 at a pH level of 7.0.

Appendix 1

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Carbonate Hardness, Potential Hydrogen and Carbon Dioxide.
The KH, pH CO2 relationship

KH pH CO2 Relationship

KH / pH	6.0	6.2	6.4	6.6	6.8	7.0	7.2	7.4	7.6	7.8	8.0
0.25	8	5	3	2	1	0.8	0.5	0.3	0.2	0.1	0.1
0.50	15	9	6	4	2	2	0.9	0.6	0.4	0.2	0.2
0.75	23	14	9	6	4	2	1	0.9	0.6	0.4	0.2
1.00	30	19	12	8	5	3	2	1	0.8	0.5	0.3
1.25	38	24	15	9	6	4	2	1	0.9	0.6	0.4
1.50	45	28	18	11	7	5	3	2	1	0.7	0.5
1.75	53	33	21	13	8	5	3	2	1	0.8	0.5
2.00	60	38	24	15	10	6	4	2	2	1.0	0.6
2.50	75	47	30	19	12	8	5	3	2	1	0.8
3.00	90	57	36	23	14	9	6	4	2	1	0.9
3.50	105	66	42	26	17	11	7	4	3	2	1
4.00	120	76	48	30	19	12	8	5	3	2	1
4.50	135	85	54	34	21	14	9	5	3	2	1
5.00	150	95	60	38	24	15	9	6	4	2	2
6.00	180	114	72	45	29	18	11	7	5	3	2
7.00	210	133	84	53	33	21	13	8	5	3	2
8.00	240	151	96	60	38	24	15	10	6	4	2
9.00	270	170	107	68	43	27	17	11	7	4	3
10.00	300	189	119	75	48	30	19	12	8	5	3
15.00	450	284	179	113	71	45	28	18	11	7	5
20.00	600	379	239	151	95	60	38	24	15	10	6

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Carbonate Hardness, Potential Hydrogen and Carbon Dioxide.
The KH, pH CO2 relationship

KH pH CO2 Relationship

KH / pH	5.0	5.1	5.2	5.3	5.4	5.5	5.6	5.7	5.8	5.9	6.0
0.25	75	60	47	38	30	24	19	15	12	9	8
0.50	150	119	95	75	60	47	38	30	24	19	15
0.75	225	179	142	113	90	71	57	45	36	28	23
1.00	300	238	189	150	119	95	75	60	48	38	30
1.25	375	298	237	188	149	119	94	75	59	47	38
1.50	450	357	284	226	179	142	113	90	71	57	45
1.75	525	417	331	263	209	166	132	105	83	66	53
2.00	600	477	379	301	239	190	151	120	95	76	60
2.25	675	536	426	338	269	213	170	135	107	85	68
2.50	750	596	473	376	299	237	188	150	119	94	75
2.75	825	655	521	413	328	261	207	165	131	104	83
3.00	900	715	568	451	358	285	226	180	143	113	90
3.25	975	774	615	489	388	308	245	195	155	123	98
3.50	1050	834	663	526	418	332	264	210	166	132	105
3.75	1125	894	710	564	448	356	283	224	178	142	113
4.00	1200	953	757	601	478	379	301	239	190	151	120
4.25	1275	1013	804	639	508	403	320	254	202	161	128
4.50	1350	1072	852	677	537	427	339	269	214	170	135
4.75	1425	1132	899	714	567	451	358	284	226	179	143
5.00	1500	1191	946	752	597	474	377	299	238	189	150

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KH pH CO2 Relationship

KH / pH	4.0	4.1	4.2	4.3	4.4	4.5	4.6	4.7	4.8	4.9	5.0
0.25	750	596	473	376	299	237	188	150	119	94	75
0.50	1500	1191	946	752	597	474	377	299	238	189	150
0.75	2250	1787	1420	1128	896	712	565	449	357	283	225
1.00	3000	2383	1893	1504	1194	949	754	599	475	378	300
1.25	3750	2979	2366	1879	1493	1186	942	748	594	472	375
1.50	4500	3574	2839	2255	1791	1423	1130	898	713	567	450
1.75	5250	4170	3313	2631	2090	1660	1319	1048	832	661	525
2.00	6000	4766	3786	3007	2389	1897	1507	1197	951	755	600

Appendix 2

Perpetual Preservation System™

Category		NO3 – PO4	Ca -Mg	KH – pH – CO2	Trace Elements
Article		Volume 1, Issue 1 Volume 2, Issue 1	Volume 2, Issue 2	Volume 2, Issue 3	Volume 2, Issue 4
Required Levels		NO3 Low-Normal-High PO4 Low-Normal-High	Ca 20 - 30 ppm Mg 5 - 10 ppm	KH Use Table pH Specie selectable CO2 30 - 40 ppm	See Article
Test Kits		NO3, PO4	GH, Ca	KH, pH	
Solution Fertilizer		SS Standard Solution PF PO4-Free Solution NF NO3-Free Solution	Mg Solution		TE Solution
Dry Fertilizer			Discus Mix	CaCO3 Calcium Carbonate NaHCO3 Baking Soda	