LIME
The Versatile Chemical

Fact Sheet

Lime Terminology, Standards & Properties

LIME TERMINOLOGY

Quicklime, the product of calcination of limestone, consists of the oxides of calcium and magnesium. The primary forms of quicklime are:

- High calcium quicklime - derived from limestone containing 0 to 5 percent magnesium carbonate.
- Dolomitic quicklime - derived from limestone containing 35 to 46 percent magnesium carbonate.

Hydrated lime is a dry powder obtained by treating quicklime with sufficient water to satisfy its chemical affinity for water, thereby converting the oxides to hydroxides. Depending upon the type of quicklime used and the hydrating conditions employed, the amount of water in chemical combination varies, as follows:

- High calcium hydrated lime - high calcium quicklime produces a hydrated lime containing generally 72 to 74 percent calcium oxide and 23 to 24 percent chemically combined water.
- Dolomitic hydrated lime (normal) - under atmospheric hydrating conditions only the calcium oxide fraction of dolomitic quicklime hydrates, producing a hydrated lime of the following chemical composition: 46 to 48 percent calcium oxide, 33 to 34 percent magnesium oxide, and 15 to 17 percent chemically combined water.
- Dolomitic hydrated lime (pressure) - this lime is produced from dolomitic quicklime under pressure, which results in hydrating all of the magnesium oxide as well as all of the calcium oxide, producing the following chemical composition: 40 to 42 percent calcium oxide, 29 to 30 percent magnesium oxide, and 25 to 27 percent chemically combined water.

Quicklime is a white to gray solid having a crystalline structure. Quicklime is highly reactive with water, generating considerable heat in the hydration process. This material will react with the moisture in the air, and as such, it can be used as a desiccant. In the presence of moisture, lime reacts slowly with carbon dioxide in the air, reforming calcium carbonate. As a chemically active material it is desirable to reduce atmospheric exposure during handling and storage to a minimum. Hydrated lime, though only slightly soluble in water, forms suspensions easily; the resulting solution and suspension is strongly alkaline, possessing a pH of 12.4.

Quicklime is commercially available by pneumatic tanker truck, rail hopper car, or in bulk or in paper bags.

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It is available in a number of sizes as follows (definitions derived from ASTM standard C51):

- Large lump lime - the product with a maximum size of eight inches in diameter.
- Crushed or pebble lime - the product ranging in size from about 1/4 to 2 ½ in.
- Ground lime - the product of a size 1/4 inches and smaller.
- Pulverized lime - the product resulting from a more intense grinding than is used to produce ground lime. A typical size is substantially all passing a No. 20 sieve.
- Pelletized lime - one inch sized pellets or briquettes, molded from quicklime fines.

For detailed information on the handling and storage of lime, equipment for application of lime, lime slaking and slurry handling, and factors affecting the selection of lime, please refer to "Lime Handling, Application & Storage," published by the National Lime Association.

Hydrated lime is generally shipped in 50-pound paper bags and in pneumatic tank trucks or railhopper cars. Due to the hydration process hydrated lime is by necessity of fine particle size. Normal grades of hydrated lime suitable for most chemical purposes will have 85 percent or more passing a 200-mesh sieve, while for special applications hydrated lime may be obtained as fine as 99.5 percent passing a 325-mesh sieve.

LIME STANDARDS & GUIDES

Standards of the American Society for Testing and Materials (ASTM) contain product specifications for certain applications, describe chemical and physical test methods, and address nomenclature. ASTM standards and guides related to lime include the following:

Soil Stabilization:	
C977	Specification for Quicklime and Hydrated Lime for Soil Stabilization
C593	Specification for Fly Ash & Other Pozzolans for use with Lime for Soil Stabilization
Test Methods:	
D6276	Using pH to Estimate the Lime Requirement for Soil Stabilization
D5102	Unconfined Compressive Strength of Compacted Soil-Lime Mixtures
Asphalt:	
C1097	Specification for Hydrated Lime for Use in Asphalt
D4867	Test Method for the Effect of Moisture on Asphalt Paving Mixtures
Environmental Uses:	
C1529	Specification for Quicklime and Hydrated Lime for Environmental Uses
D6249	Guide for Alkaline Stabilization of Wastewater Treatment Plant Residuals
Test Methods:	
C400	Quicklime and Hydrated Lime for Neutralization of Waste Acid
C1318	Determination of Total Neutralizing Capability and Dissolved Calcium and Magnesium Oxide in Lime for Flue Gas Desulfurization (FGD)

Building Lime:	
C207	Hydrated Lime for Masonry Purposes
C206	Finishing Hydrated Lime
C821	Lime for Use with Pozzolans
C5	Quicklime for Structural Purposes
C270	Mortar for Unit Masonry
Other Applications:	
C911	Quicklime and Hydrated Lime for Selected Chemical and Industrial Uses
D5050	Guide for Commercial Use of Lime Kiln Dusts
E1266	Practice for Processing Mixtures of Lime, Fly Ash, and Heavy Metal Wastes in Structural Fills and Other Construction Applications
C602	Specification for Agricultural Liming Materials
General Testing:	
C25	Chemical Analysis of Quicklime and Hydrated Lime
C110	Physical Testing of Quicklime and Hydrated Lime
C1271	X-Ray Spectrometric Analysis of Lime
C1301	Major & Trace Elements in Lime by Inductively Coupled Plasma Atomic Emission Spectroscopy (ICP) & Atomic Absorption (AA)
Other:	
C51	Terminology Relating to Lime
C50	Sampling, Sample Preparation, Packaging, & Marking of Lime Products

Copies of these and other lime-related standards may be purchased from ASTM, 100 Barr Harbor Drive, West Conshohocken, PA 19428-2959 (www.astm.org). Other relevant standards have been issued by the American Water Works Association (AWWA, www.awwa.org) and the American Association of State Highway and Transportation Officials (AASHTO, www.transportation.org).

PROPERTIES OF TYPICAL COMMERCIAL LIME PRODUCTS

Quicklimes

	High Calcium	Dolomitic
Primary Constituents	CaO	CaO•MgO
Specific Gravity	3.2-3.4	3.2-3.4
Bulk Density (Pebble Lime), lb./cu. ft.	55-60*	55-60*
Specific Heat at 100° F., Btu/lb	0.19	0.21
Angle of Repose	55° **	55° **

Hydrates

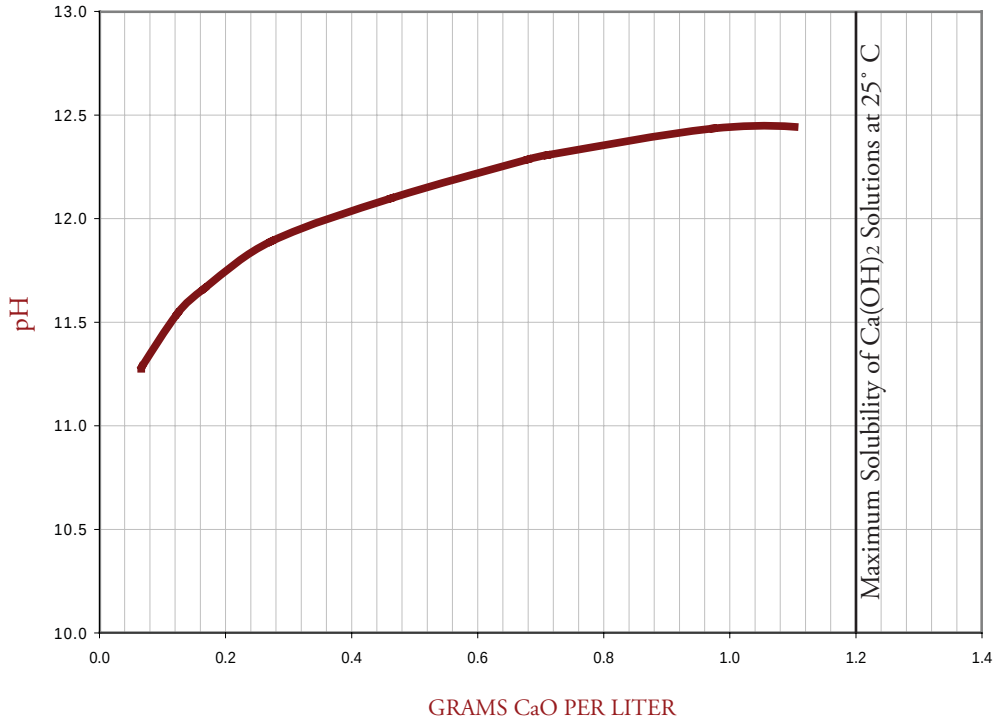
	High Calcium	Normal Dolomitic	Pressure Dolomitic
Primary Constituents	$Ca(OH)_2$	$Ca(OH)_2$•MgO	$Ca(OH)_2$ •$Mg(OH)_2$
Specific Gravity	2.3-2.4	2.7-2.9	2.4-2.6
Bulk Density, lb./cu. ft.	25-35 *	25-35 *	30-40 *
Specific Heat at 100° F., Btu/lb.	0.29	0.29	0.29
Angle of Repose	70° **	70° **	70° **

*/ In some instances these values may be extended. The test method described in ASTM C110 can be used for determining bulk density values. In calculating storage volume requirements, the lower figure should be used, whereas the higher value should be used for gross weight in designing safety factors.

**/ The angle of repose for both types of lime (hydrate in particular) varies considerably with mesh, moisture content, degree of aeration, and physical characteristics of the lime. (E.g., for quicklime it generally varies from 50 to 55 degrees and for hydrated lime it may range as much as 15 to 80 degrees.)

pH OF CALCIUM HYDROXIDE SOLUTIONS AT 25 DEGREES C.

Graph Showing pH Curve of Calcium Hydroxide Solutions at 25° C



CaO gms. per l.	pH
0.064	11.27
0.065	11.28
0.122	11.54
0.164	11.66
0.271	11.89
0.462	12.10
0.680	12.29
0.710	12.31
0.975	12.44
1.160	12.45

Because the solubility of lime decreases as the temperature increases (see page 5), the pH of lime solutions is correspondingly lower at higher temperatures (see page 6).

SOLUBILITY OF CALCIUM HYDROXIDE IN WATER

Grams per 100 gms. sat. sol.

t °C	CaO	$Ca(OH)_2$
0	0.140	0.185
10	0.133	0.176
20	0.125	0.165
25	0.120	0.159
30	0.116	0.153
40	0.106	0.140
50	0.097	0.128
60	0.088	0.116
70	0.079	0.104
80	0.070	0.092
90	0.061	0.081
100	0.054	0.071

The solubility of commercial limes in water does not vary more than 7% from the solubility of pure calcium hydroxide. The differences are probably due to the presence of traces of sodium and potassium hydroxide in commercial limes. The presence of magnesia, silica, and carbonate have no effect upon the solubility of ordinary lime, but may have a marked effect upon its rate of solution. Particle size may also influence solubility.

TEMPERATURE vs. pH OF A SATURATED CALCIUM HYDROXIDE SOLUTION

Temperature °C	pH
0	13.423
5	13.207
10	13.003
15	12.810
20	12.627
25	12.454
30	12.289
35	12.133
40	11.984
45	11.841
50	11.705
55	11.574
60	11.449

Conversion Formula:

pH correction = [0.03 pH units/1.0 deg. C] x [Measured Temp deg. C - 25]

This equation indicates that for each degree difference between the measured temperature in degrees C and 25 degrees C, there is a change in pH of 0.03 units. Thus, for example, if a pH of 12 is measured at 20 degrees C, the pH at 25 degrees C is 11.85 [12 + (0.03 x -5)]. There is an inverse relationship between temperature and pH.

Note that the temperature correction controls on pH meters do NOT compensate for the changes in solubility created by changes in temperature. The pH meter controls address probe temperature and conductivity changes only.

STRENGTH OF LIME SUSPENSIONS

Milk-of-lime Suspensions		Lime Content*				% Solids $Ca(OH)_2$ in Water
Specific Gravity at 15 C.	Degrees Baumé (Bur. Stds. Scale)	Grams CaO per liter	Grams Ca(OH)2 per liter	Lbs. CaO per U.S. gal.	Lbs. CaO per cu. ft.	
1.010	1.44	11.7	15.5	.097	.07	1.6
1.020	2.84	24.4	32.2	.203	1.5	3.2
1.030	4.22	37.1	49.0	.309	2.3	4.8
1.040	5.58	49.8	65.8	.415	3.1	6.3
1.050	6.91	62.5	82.6	.520	3.9	7.9
1.060	8.21	75.2	99.4	.626	4.7	9.4
1.070	9.49	87.9	116	.732	5.5	10.8
1.080	10.74	100	132	.833	6.3	12.3
1.090	11.97	113	149	.941	7.1	13.7
1.100	13.18	126	166	1.05	7.9	15.2
1.110	14.37	138	182	1.15	8.7	16.4
1.120	15.54	152	201	1.27	9.5	18.0
1.130	16.68	164	217	1.37	10.3	19.3
1.140	17.81	177	234	1.47	11.1	20.5
1.150	18.91	190	251	1.58	11.9	21.8
1.160	20.00	203	268	1.69	12.7	23.1
1.170	21.07	216	285	1.80	13.5	24.4
1.180	22.12	229	303	1.91	14.3	25.6
1.190	23.15	242	320	2.02	15.1	27.0
1.200	24.17	255	337	2.12	15.9	28.0
1.210	25.16	268	354	2.23	16.7	29.2
1.220	26.15	281	371	2.34	17.6	30.4
1.230	27.11	294	388	2.45	18.4	31.6
1.240	28.06	307	406	2.56	19.2	32.8
1.250	29.00	321	424	2.67	20.0	33.8

*/ Data are based on a typical high calcium lime. In obtaining these data, the milk of lime was placed in a wide cylinder, slowly rotating to permit agitation. The hydrometer was inserted and allowed to sink slowly; the reading taken when it stopped. In the case of a thin slurry, the reading must be taken quickly before the lime settles, while in the case of a thick cream of lime, duplicate readings should be taken to assure the correct hydrometer value.

The table is for milk-of-lime suspensions. Above 30% solids some limes no longer show properties of a suspension and are quite stiff (paste). At 35% additives are often added to make the suspension pumpable. At 40% these limes are generally too stiff to pump.

Settling rates of commercial lime slurries vary widely and depend primarily upon the particle size of the lime. Finely pulverized pure limes settle slowly; on the other hand, coarse limes settle rapidly.

FORMULA FOR CALCULATING WEIGHTS OF SLURRY

For calculating the weights of slurry with varying percentages of water, the following formula may be used:

$$W = \frac{6237s}{100 - a + sa}$$

in which:

W = weight in pounds of slurry per cubic foot.
s = specific gravity of dry lime solids.
a = per cent water in slurry.

The result may be divided by 62.37 to obtain the result in grams per cubic centimeter.

SOLUBILITY OF MAGNESIUM HYDROXIDE

Magnesium hydroxide is virtually insoluble in water. At 18 and 100 degrees C. the solubilities are, respectively, 0.0098 and 0.0042 gms. $Mg(OH)_2$ per liter of saturated solution. The presence of small quantities of NaCl and Na_2SO_4 in the aqueous solution will increase the solubility of $Mg(OH)_2$ slightly.

HEATS OF REACTION AT 25 DEGREES C.

Hydration or Slaking

$CaO + H_2O$	$= Ca(OH)_2$	heat evolved	= 15,300 cal/gram mol.
			273 cal/gram
			= 27,500 BTU/lb.mol.
			490 BTU/lb.
$MgO + H_2O$	$= Mg(OH)_2$	heat evolved	= 8,800 to 10,000 cal/gram mol.
			218 to 248 cal/gram
			= 14,400 to 18,000 BTU/lb. mol.
			357 to 446 BTU/lb.

COMPARISON OF COMMON ALKALIS IN TYPICAL CHEMICAL REACTIONS

Alkali Reactions with	100% Pure Reactant lbs.	Stoichimetric Quantities of 100% Pure Alkalis[1] Required for Reactions		
		CaO equiv. lbs.	NaOH lbs.	Na_2CO_3 lbs.
Sulfuric Acid	100	57.2	81.6	108.1
Hydrochloric Acid	100	76.9	109.7	145.3
Nitric Acid	100	44.5	63.5	84.1
Hydrofluoric Acid	100	140.1	200.0	264.3
Phosphoric Acid[2]	100	85.8	122.5	162.2
Sodium Cyanide and Chlorine[3]	100	228.8	326.5	
Chlorine[4]	100	79.1	112.8	

1/ Quantities specified do not include excess alkali for pH adjustment, etc., that may be required to complete reaction.

2/ Extent of reaction considered is the formation of the tribasic compounds, $Ca_3(PO_4)_2$ and Na_3PO_4.

3/ Cyanide destruction to the N_2 product, as:
$4Ca(OH)_2 + 2NaCN + 5Cl_2 \Rightarrow 4CaCl_2 + 2NaCl + N_2 + 2CO_2 + 4H_2O$.

4/ Extent of chlorination considered is the formation in water of the hypochlorites, $Ca(OCl)_2$ and NaOCl. $CaCl_2$ and NaCl are also produced in this reaction.

AKALI CONVERSION TABLE

The following table identifies equivalent weight ratios.

CaO	$Ca(OH)_2$	CaO . MgO	NaOH	Na_2CO_3
1	1.32	0.86	1.43	1.89
2	2.64	1.72	2.85	3.78
3	3.96	2.58	4.28	5.67
4	5.29	3.44	5.71	7.56
5	6.61	4.30	7.13	9.45
6	7.93	5.16	8.56	11.34
7	9.25	6.02	9.99	13.23
8	10.57	6.88	11.41	15.12
9	11.89	7.74	12.84	17.01
10	13.21	8.59	14.27	18.90
15	19.82	12.89	21.40	28.35
20	26.43	17.19	28.53	37.80
25	33.03	21.49	35.67	47.26
30	39.64	25.78	42.80	56.71
35	46.24	30.08	49.93	66.16
40	52.85	34.38	57.07	75.61
45	59.46	38.68	64.20	85.06
50	66.06	42.97	71.34	94.51
55	72.67	47.27	78.47	103.96
60	79.28	51.57	85.60	113.41
65	85.88	55.87	92.74	122.86
70	92.49	60.16	99.87	132.32
75	99.09	64.46	107.00	141.77
80	105.70	68.76	114.14	151.22
85	112.31	73.06	121.27	160.67
90	118.91	77.35	128.40	170.12
95	125.52	81.65	135.54	179.57
100	132.13	85.95	142.67	189.02

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