Standards of Titanium Products [Commercially-Pure Titanium/Corrosion-Resistant Titanium Alloys]

Classification	Standard	Chemical composition [mass%]										Tensile properties		
		C	H	O	N	Fe	Pd	Co	Ru	Ni	Ti	0.2%proof stress [MPa]	Tensile strength [MPa]	Elongation [%]
Commercially-Pure titanium	Well-formable grade	≦0.08	≦0.013	≦0.15	≦0.03	≦0.20					rem.	≧120	≧250	≧40
	JIS Class 1	≦0.08	≦0.013	≦0.15	≦0.03	≦0.20	–	–			rem.	≧165	270–410	≧27
	JIS Class 2	≦0.08	≦0.013	≦0.20	≦0.03	≦0.25	–	–			rem.	≧215	340–510	≧23
	JIS Class 3	≦0.08	≦0.013	≦0.30	≦0.05	≦0.30	–	–			rem.	≧345	480–620	≧18
	JIS Class 4	≦0.08	≦0.013	≦0.40	≦0.05	≦0.50	–	–			rem.	≧485	550–750	≧15
	ASTM/ASME Grade1	≦0.08	≦0.015	≦0.18	≦0.03	≦0.20	–	–			rem.	138–310	≧240	≧24
	ASTM/ASME Grade2	≦0.08	≦0.015	≦0.25	≦0.03	≦0.30	–	–			rem.	275–450	≧345	≧20
	ASTM/ASME Grade3	≦0.08	≦0.015	≦0.35	≦0.05	≦0.30	–	–			rem.	380–550	≧450	≧18
	ASTM/ASME Grade4	≦0.08	≦0.015	≦0.40	≦0.05	≦0.50	–	–			rem.	483–655	≧550	≧15
Corrosion-resistant titanium alloys	JIS Class 17	≦0.08	≦0.015	≦0.18	≦0.03	≦0.20	0.04–0.08	–			rem.	≧170	240–380	≧24
	JIS Class 19	≦0.08	≦0.015	≦0.25	≦0.03	≦0.30	0.04–0.08	0.20–0.80			rem.	≧275	345–515	≧20
	JIS Class 20	≦0.08	≦0.015	≦0.35	≦0.05	≦0.30	0.04–0.08	0.20–0.80			rem.	≧380	450–590	≧18
	ASTM/ASME Gr.17	≦0.08	≦0.015	≦0.18	≦0.03	≦0.20	0.04–0.08	–			rem.	138–310	≧240	≧24
	ASTM/ASME Gr.30	≦0.08	≦0.015	≦0.25	≦0.03	≦0.30	0.04–0.08	0.20–0.80			rem.	275–450	≧345	≧20
	ASTM/ASME Gr.31	≦0.08	≦0.015	≦0.35	≦0.05	≦0.30	0.04–0.08	0.20–0.80			rem.	380–550	≧450	≧18
	JIS Class 11	≦0.08	≦0.013	≦0.15	≦0.03	≦0.20	0.12–0.25	–			rem.	≧165	270–410	≧27
	JIS Class 12	≦0.08	≦0.013	≦0.20	≦0.03	≦0.25	0.12–0.25	–			rem.	≧215	340–510	≧23
	JIS Class 13	≦0.08	≦0.013	≦0.30	≦0.05	≦0.30	0.12–0.25	–			rem.	≧345	480–620	≧18
	ASTM/ASME Grade11	≦0.08	≦0.015	≦0.18	≦0.03	≦0.20	0.12–0.25	–			rem.	138–310	≧240	≧24
	ASTM/ASME Grade7	≦0.08	≦0.015	≦0.25	≦0.03	≦0.30	0.12–0.25	–			rem.	275–450	≧345	≧20
	JIS Class 21	≦0.08	≦0.015	≦0.10	≦0.03	≦0.20			0.04–0.06	0.40–0.60	rem.	≧170	275–450	≧24
	JIS Class 22	≦0.08	≦0.015	≦0.15	≦0.03	≦0.30			0.04–0.06	0.40–0.60	rem.	≧275	410–530	≧20
	ASTM/ASME Grade13	≦0.08	≦0.015	≦0.10	≦0.03	≦0.20			0.04–0.06	0.4–0.6	rem.	≧170	≧275	≧24
	ASTM/ASME Grade14	≦0.08	≦0.015	≦0.15	≦0.03	≦0.30			0.04–0.06	0.4–0.6	rem.	≧275	≧410	≧20

Standards of Titanium Products [Titanium Alloys]

Alloy classification	Nominal composition or company standard	Product form: Plate	Sheet	Welded tube	Bar/ wire rod	Chemical composition(mass%): Al	V	Mo	Cr	Zr	Sn	Si	Cu	Nb	Fe	O	N	C	Examples of Tensile properties at room temperature (minimum values): Heat treatment *	0.2%proof stress min.(MPa)	Tensile strength min.(MPa)	Elongation min. (%)	Advantageous features	Main related standards, etc.
$\alpha + \beta$ alloy	Ti-3Al-2.5V		○*	○*	○	2.5–3.5	2.0–3.0								≦0.25	≦0.15	≦0.03	≦0.08	Annealing	485	620	15	Good cold formability	JIS Class 61
																				483	620	15		ASTM Gr.9
	Ti-6Al-4V				○	5.50–6.75	3.50–4.50								≦0.30	≦0.20	≦0.05	≦0.08	Annealing	827	895	10	Versatility	AMS4928
																			STA	1070	1140	10		AMS6930, 6931(AMS-T-9047)
						5.5–6.75	3.5–4.5								≦0.40	≦0.20	≦0.05	≦0.08	Annealing	825	895	10		JIS Class 60
																				828	895	10		ASTM Gr.5
	Ti-6Al-4V ELI				○	5.5–6.5	3.5–4.5								≦0.25	≦0.13	≦0.03	≦0.08	Annealing	755	825	10	Good low-temperature toughness	JIS Class 60E ASTM Gr.23, ASTM F136
	Ti-6Al-6V-2Sn				○	5.00–6.00	5.00–6.00				1.50–2.50		0.35–1.00		0.35–1.00	≦0.20	≦0.04	≦0.05	Annealing STA	965 1105	1035 1205	10 8	Good hardenability	AMS4971, 6935, 6936
	Ti-6Al-2Sn-4Zr-2Mo-0.08Si				○	5.50–6.50		1.80–2.20		3.60–4.40	1.80–2.20	0.06–0.10			≦0.10	≦0.15	≦0.05	≦0.05	Annealing STA	825 860	895 930	10 10	Good heat resistance	AMS4975, 4976
	Ti-6Al-2Sn-4Zr-6Mo				○	5.50–6.50		5.50–6.50		3.60–4.40	1.75–2.25				≦0.15	≦0.15	≦0.04	≦0.04	STA	1105	1170	10	Good creep resistance	AMS4981, 6906
β alloy	Ti-3Al-8V-6Cr-4Mo-4Zr				○	3.0–4.0	7.5–8.5	3.5–4.5	5.5–6.5	3.5–4.5					≦0.30	≦0.14	≦0.03	≦0.05	ST	759	793	15	Good cold formability	AMS4957, 4958, 6920, 6921
																≦0.12			STA	1100	1170	4	Good age hardenability	ASTM Gr.19, β-C
	Ti-10V-2Fe-3Al				○*	2.6–3.4	9.0–11.0								1.6-2.2	≦0.13	≦0.05	≦0.05	STA	1103	1193	4	High strength and high toughness High fatigue strength Good hardenability	AMS4983, 4984, 4986, 4987
	Ti-15V-3Cr-3Sn-3Al		○*		○	2.5–3.5	14.0–16.0		2.5–3.5		2.5–3.5				≦0.25	≦0.13	≦0.05	≦0.05	ST STA	689 965	703 1100	12 7	Good Cold formability Good age hardenability	AMS4914
Company standard product	Super-TIX™800		○		○										0.50–1.50	0.25–0.45	≦0.02	≦0.08	Annealing	550	700	10	High strength between Class 61 (Gr. 9) and Class 60 (Gr. 5)	Original
	Super-TIX™800N	○													0.50–1.50	0.20–0.40	0.02–0.05	≦0.08	Annealing	550	700	10	High strength between Class 61 (Gr. 9) and Class 60 (Gr. 5)	Original
	Super-TIX™51AF(Ti-5Al-1Fe)		○		○	4.50–5.50									0.50–1.50	≦0.25	≦0.05	≦0.08	Annealing	700	800	10	High strength comparable to Class 60 (Gr. 5)	Original
	Super-TIX®523AFM(Ti-5Al-2Fe-3Mo)				○	4.50–5.50		2.5–3.5							1.50–2.50	≦0.25	≦0.05	≦0.08	Annealing	870	950	10	Strength superior to Class 60 (Gr. 5)	Original
	Super-TIX™05CU(Ti-0.5Cu)	○											0.40–0.70		≦0.03	0.02–0.06	≦0.03	≦0.08	Annealing	165	270	27	Homogeneous structure	Original
	Super-TIX™10CU(Ti-1Cu)		○	○									0.80–1.20		≦0.06	0.02–0.07	≦0.01	≦0.08	Annealing	270	360	35	Good heat resistance	Original
	Super-TIX™10CUNB(Ti-1Cu-0.5Nb)		○	○									0.80–1.20	0.40–0.60	≦0.06	0.02–0.07	≦0.01	≦0.08	Annealing	270	360	35	Good heat resistance	Original
	Super-TIX™10CSSN(Ti-1Cu-1Sn-0.35Si-0.25Nb)		○	○								0.25–0.45	0.80–1.20	0.20–0.35	≦0.06	0.02–0.07	≦0.01	≦0.08	Annealing	270	395	20	Good heat resistance	Original
	Ti-3Al-5V		○	○*		2.50–3.50	4.50–5.50								≦0.20	≦0.12	≦0.05	≦0.08	Annealing	670	810	10	Good cold formability	Original
	Ti-20V-4Al-1Sn		○		○	3.0–3.6	19.0–22.5				0.80–1.20				≦0.20	≦0.20	≦0.05	≦0.08	ST STA	600 950	630 1050	15 10	Good cold formability	Original

○* : Please consult us when placing an order.

*ST : Solution treatment STA : Solution treatment + aging

Technical Data

Physical Properties

The advantageous physical properties of pure titanium are as follows.

①Light weight [Specific gravity] (60% of specific gravity of steel and about 1.7 times that of aluminum)
②Low thermal expansion [Hermal expansion coefficient]] (ne-half that of 18-8 stainless steel and one-third that of aluminum)
③Low hear conductivity [Heat conductivity] (nearly the same as 18-8 stainless steel)
④Low electric conductivity [Electric conductivity] (about 3% of copper)
⑤High flexibility [Longitudinal elastic modulus] (one-half of iron or stainless steel and the same as copper)
⑥6 Non-magnetism [Magnetic permeability] (non-magnetic material; magnetic permeability = 1.0001)

Comparison of physical properties between titanium and other metallic materials

Item	Atomic number	Atomic weight	Specific gravity	Melting point (℃)	Linear expansion coefficient (/K)	Specific heat (KJ/Kg·K)	Thermal conductivity (w/m·K)	Specific resistivity (μΩ·m)	Electric conductivity (% ratio to copper)	Young's modulus (GPa)
Titanium	22	47.90	4.51	1668	8.4×10^{-6}	0.519	17	0.55	3.1	106.3
titanium alloy Ti-6Al-4V	—	—	4.43	1650	8.8×10^{-6}	0.610	7.5	1.71	1.1	110
Iron	26	55.85	7.9	1530	12×10^{-6}	0.460	63	0.097	18	205.8
18-8stainless steel (SUS 304)	—	—	7.9	1400 ~1420	17×10^{-6}	0.502	16	0.72	2.4	199.9
Aluminum	13	26.97	2.7	650	23×10^{-6}	0.879	205	0.027	64	69.1
Aluminum alloy (7075)	—	—	2.8	476 ~638	23×10^{-6}	0.962	121	0.058	30	71.5
Magnesium	12	24.32	1.7	650	25×10^{-6}	1.004	159	0.043	40	44.8
Nickel	28	58.69	8.9	1453	15×10^{-6}	0.460	92	0.095	18	205.8
Hastelloy C	—	—	8.9	1305	11.3×10^{-6}	0.385	13	1.3	1.3	204.4
Copper	29	63.57	8.9	1,083	17×10^{-6}	0.385	385	0.017	100	107.8

Note) 18-8 stainless steel : Cr(18%)-Ni(8%)-Fe(R)
Aluminum alloy 7075 : Super-super duralumin
[Cu(1.6%)-Mg(2.5%)-Cr(2.3%-Zn(5.6%)-Al(R) subjected to solution heat treatment and aging)
Hastelloy C : 54Ni-17Mo-15Cr-5Fe-4W

■ Properties other than those shown above
Crystal structure
α titanium (885℃ or lower) : Close-packed hexagonal lattice
β titanium (above 885℃) : Body-centered cubic lattice
Latent heat of fusion : 60.7 J/g, relative magnetic permeability : 1.0001

(Source: Japan Titanium Society)

Corrosion Resistance

Comparison of corrosion resistance between titanium and other metallic materials

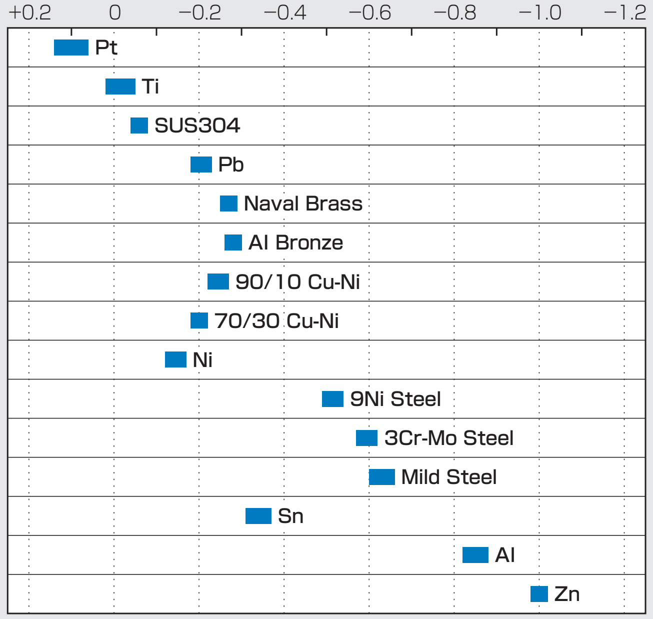
Corroding medium	Composition (%)	Temperature (℃)	Corrosion resistance: Titanium	18-8 stainless steel	Hastelloy C
Hydrochloric acid	10	24	○	×	◎
	30	24	×	×	◎
	10	80	×	—	○
	30	80	×	—	△
Sulfuric acid	10	24	△	—	◎
	50	24	×	×	◎
	10	100	×	—	◎
	50	100	×	—	◎
Nitric acid	10	24	◎	◎	◎
	50	24	◎	◎	—
	10	100	◎	◎	△
	50	100	◎	○	—
Aqua regia	HCl·HNO3 3 : 1	24	◎	×	△
		100	○	—	—
Chromic acid	5	24	◎	—	◎
Hydrogen fluoride	5	30	×	×	△
Phosphoric acid	10(with aeration)	24	○	◎	◎
	50(with aeration)	24	△	◎	◎
	10(with aeration)	100	×	◎	◎
	50(with aeration)	100	×	○	◎
Ferric chloride	10	24	◎	×	◎
	30	24	◎	×	◎
	10	100	◎	—	×
	30	100	◎	—	×
Cupric chloride	10	24	○	×	○
	30	24	○	×	○
	10	100	○	—	—
	30	100	○	—	—
Sodium chloride	10	24	◎	○	○
	40	24	◎	○	○
	10	100	◎*	○*	○
	40	100	◎*	○*	○
Calcium chloride	10	24	◎	◎	◎
	50	24	◎	○	◎
	10	100	◎*	—	◎
	50	100	◎*	×	◎
Ammonium chloride	10	24	◎	△	◎
	40	24	◎	—	◎
	10	100	◎*	—	◎
	40	100	◎*	—	◎
Magnesium chloride	10	24	◎	△	◎
	40	24	◎	○	◎
	10	100	◎*	△*	◎
	40	100	◎*	—	◎
Ferrous sulfate	10	24	◎	○	○
	50	24	◎	○	○
	10	100	◎	○	○
	50	100	◎	—	○

Corroding medium	Composition (%)	Temperature (℃)	Corrosion resistance: Titanium	18-8 stainless steel	Hastelloy C
Ammonia	10	24	◎	◎	◎
	30	24	◎	◎	◎
	10	80	◎	○	○
	30	80	◎	○	◎
Caustic soda	10	24	◎	◎	◎
	50	24	◎	◎	—
	10	100	◎	◎	◎
	50	100	○	○	◎
Carbonic soda	10	24	◎	◎	◎
	30	24	—	—	—
	10	100	◎	◎	◎
	30	100	◎	◎	◎
Hydrogen sulfide	Dry gas	24	◎	△	◎
	Wet gas	24	◎	○	○
Chlorine	Dry gas	24	×	—	◎
	Wet gas	24	◎	—	△
	Dry gas	100	—	◎	○
	Wet gas	90	◎	—	△
Sulfur dioxide	Dry gas	30~60	◎	—	—
	Wet gas	30~90	◎	—	—
Seawater	Rapidly flowing water	24	◎	—	—
	Still water	100	◎*	—	◎
Acetic acid	10	24	◎	◎	◎
	60	24	◎	◎	◎
	10	100	◎	◎	◎
	60	100	◎	○	◎
Formic acid	10	24	○	○	◎
	50	24	○	○	◎
	10	100	○	×	◎
	30	100	×	×	◎
Lactic acid	10	24	◎	○	○
	50	24	◎	○	◎
	10	100	◎	○	○
	50	100	◎	×	○
Oxalic acid	10	24	○	○	○
	20	52	×	—	○
	50	24	—	○	○
	10	100	—	—	○
	50	100	—	×	○
Citric acid	10	24	◎	○	◎
	50	24	◎	○	◎
	10	100	◎	○	◎
	50	100	×	×	◎

Note) *There are cases in which pitting or other local corrosion occurs with the material.
Corrosion rate ◎ : <0.127 ○ : <0.127~0.508
△ : 0.508~1.27 × : >1.27mm/year
(Source: Japan Titanium Society)

Corrosion Resistance in Seawater

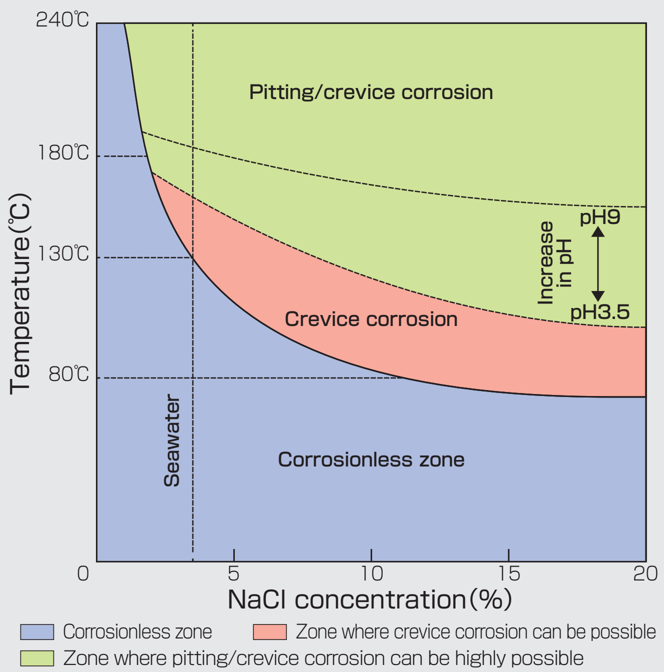
Corrosion potential in seawater (flowing water)



Air saturation in seawater(25℃)

Use of Sumitomo Metal's brochure : Since 2007

Influences of temperature, concentration and pH on pitting/crevice corrosion of commercially pure titanium in salty water

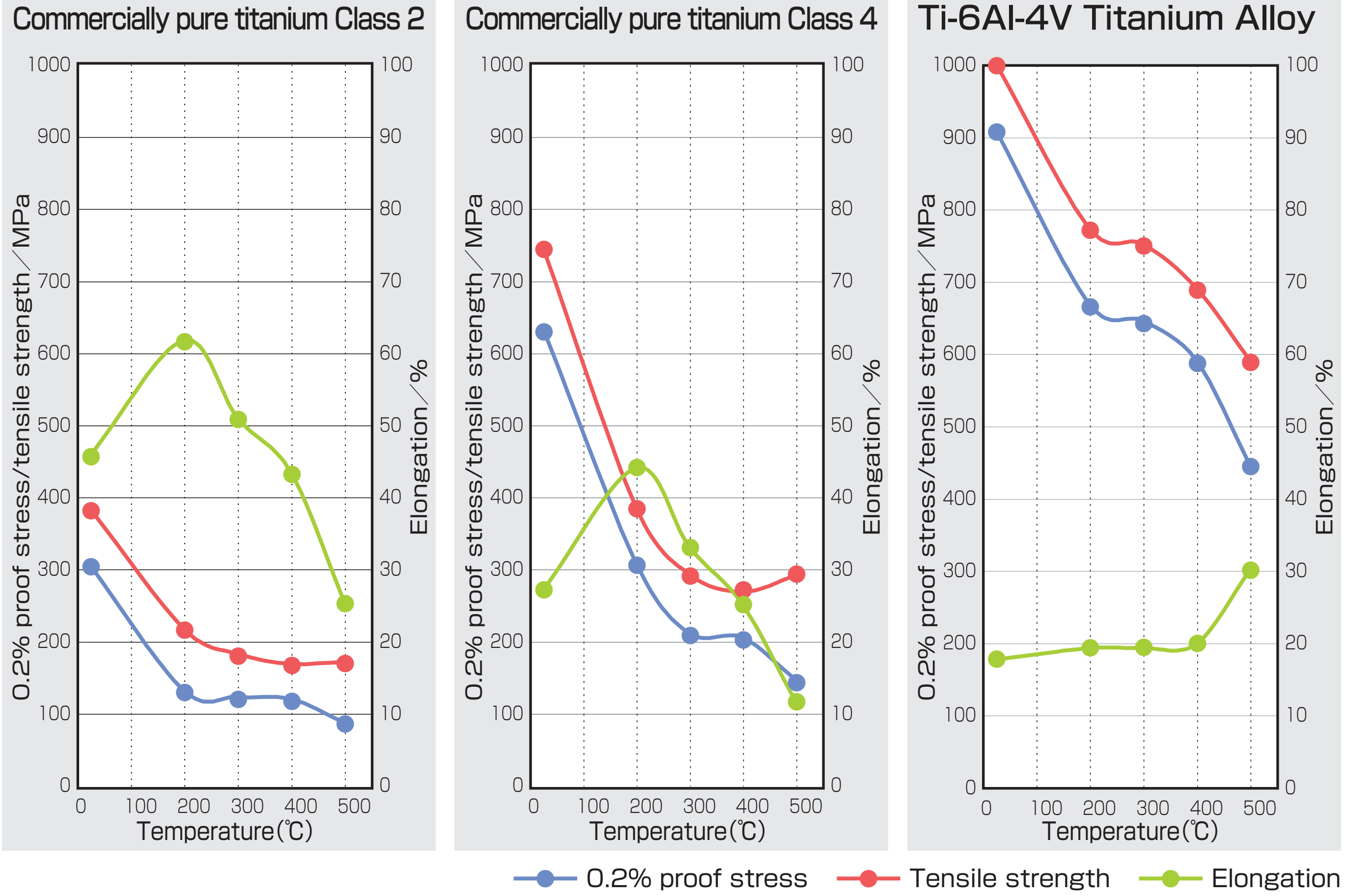


Use of Sumitomo Metal's brochure : Since 2007

Orders of Stabilization of Metals

	Order of thermodynamic stabilization	Order of practical stabilization in solution	
1	Gold	Rhodium	1
2	Iridium	Niobium	2
3	Platinum	Tantalum	3
4	Rhodium	Gold	4
5	Palladium	Iridium	5
6	Mercury	Platinum	6
7	Silver	Titanium	7
8	Copper	Palladium	8
9	Bismuth	Mercury	9
10	Arsenic	Gallium	10
11	Carbon	Zirconium	11
12	Lead	Silver	12
13	Nickel	Tin	13
14	Cobalt	Copper	14
15	Cadmium	Beryllium	15
16	Iron	Aluminum	16
17	Tin	Chromium	17
18	Molybdenum	Bismuth	18
19	Tungsten	Tungsten	19
20	Gallium	Iron	20
21	Zinc	Nickel	21
22	Niobium	Cobalt	22
23	Tantalum	Arsenic	23
24	Chromium	Carbon	24
25	Vanadium	Lead	25
26	Manganese	Cadmium	26
27	Zirconium	Zinc	27
28	Aluminum	Molybdenum	28
29	Titanium	Vanadium	29
30	Beryllium	Magnesium	30
31	Magnesium	Manganese	31

Tensile Properties in High Temperature



Clarke Number(Note)

Rank	Element		Proportion of existence(%)	Cumulative total
1	Oxygen	O	49.50	49.5
2	Silicon	Si	25.80	75.3
3	Aluminum	Al	7.56	82.9
4	Iron	Fe	4.70	87.6
5	Calcium	Ca	3.39	91.0
6	Sodium	Na	2.63	93.6
7	Potassium	K	2.40	96.0
8	Magnesium	Mg	1.93	97.9
9	Hydrogen	H	0.87	98.8
10	Titanium	Ti	0.46	99.2
11	Chlorine	Cl	0.19	99.4
12	Manganese	Mn	0.09	99.5
13	Phosphorus	P	0.08	99.6
14	Carbon	C	0.08	99.7
15	Sulfur	S	0.06	99.7
16	Nitrogen	N	0.03	99.8
17	Fluorine	F	0.03	99.8
18	Rubidium	Rb	0.03	99.8
19	Barium	Ba	0.02	99.9
20	Zirconium	Zr	0.02	
21	Chromium	Cr	0.02	
22	Strontium	Sr	0.02	
23	Vanadium	V	0.015	
24	Nickel	Ni	0.010	
25	Copper	Cu	0.010	
26	Tungsten	W	0.006	
27	Lithium	Li	0.006	
28	Cerium	Ce	0.005	
29	Cobalt	Co	0.004	
30	Tin	Sn	0.004	

Note) Clarke Number is defined as orders in composition of element to be existing in upper crust of the earth. (Source: Kagaku Daijiten(Chemical Encyclopedia))
Titanium is the 4th most abundant of practical metals existing in upper crust of the earth, following Aluminum, Iron and Magnesium.