ALKALI METALS

METALLIC RADIUS (pm)

$Li(152) < Na(186) < K(227) < Rb(248) < Cs(265)$

IONIC RADIUS (gas phase: pm)

$Li^{+}(76) < Na^{+}(102) < K^{+}(227) < Rb^{+}(248) < Cs^{+}(276)$

IONIC RADIUS (aqueous phase: pm)

$Li^{+}(340) > Na^{+}(276) > K^{+}(232) > Rb^{+}(\approx 228) > Cs^{+}(\approx 228)$

IONISATION ENERGY (kJ/mol)

$Li(520) > Na(496) > K(419) > Rb(403) > Cs(376)$

ELECTRONEGATIVITY

$Li(1) > Na(0.9) > K(0.8) > Rb(0.78) > Cs(0.7)$

DENSITY (gm/cm^3)

$Li(0.53) < K(0.86) < Na(0.97) < Rb(1.53) < Cs(1.90)$

MELTING POINT (K)

$Li(454) > Na(371) > K(336) > Rb(312) > Cs(302)$

BOILING POINT (K)

$Li(1615) > Na(1156) > K(1032) > Rb(961) > Cs(944)$

HYDRATION ENERGY (kJ/mol)

$Li^{+}(-506) > Na^{+}(-406) > K^{+}(-330) > Rb^{+}(-310) > Cs^{+}(-276)$

REDUCING NATURE (SRP: Volts)

Li(-3.04) > Cs(-2.927) > Rb(-2.930) > K(-2.925) > Na(-2.714)

IONIC MOBILITY AT INFINITE DOLUTION

Li^+ (33.5) < Na^+ (43.5) < K^+ (64.5) < Rb^+ (67.5) < Cs^+ (68)

NOTE: The melting and boiling points of alkali metals are very low because the metallic bonds in them are quite weak. Softness of metal increases down the group (Li is much harder). Li behaves abnormally as compared to other metals of the same group because of its small size.

The alkali metals and their salts impart a characteristic colour to flame

	Li	Na	K	Rb	Cs
Colour	Crimson Red	Golden Yellow	Pale Violet	Violet	Sky Blue
λ(nm)	670.8	589.2	766.5	780.0	455.5

ALKALINE EARTH METALS

METALLIC RADIUS (pm)

Be(111) < Mg(160) < Ca(197) < Sr(215) < Ba(222)

IONIC RADIUS (gas phase: pm)

Be^{2+} (31) < Mg^{2+} (72) < Ca^{2+} (100) < Sr^{2+} (118) < Ba^{2+} (135)

FIRST IONISATION ENERGY (kJ/mol)

Be(899) > Mg(737) > Ca(590) > Sr(549) > Ba(503)

SECOND IONISATION ENERGY (kJ/mol)

Be(1757) > Mg(1450) > Ca(1145) > Sr(1064) > Ba(965)

ELECTRONEGATIVITY

Be(1.47) > Mg(1.23) > Ca(1.04) > Sr(1) > Ba(.97)

DENSITY (gm/cm^3)

Ba(3.59) > Sr(2.63) > Be(1.84) > Mg(1.74) < Ca(1.55)

MELTING POINT (K)

Be(1560) < Ca(1124) < Sr(1062) < Ba(1002) < Mg(924)

BOILING POINT (K)

Be(2745) < Ba(2072) < Ca(1767) < Sr(1655) < Mg(1363)

HYDRATION ENERGY (kJ/mol)

Be(-2494) > Mg(-1921) > Ca(-1577) > Sr(-1443) > Ba(-1305)

REDUCING NATURE (SRP: Volts)

Be(-1.97) < Mg(-2.36) < Ca(-2.84) < Sr(-2.89) < Ba(-2.92)

Ion	Colour
Ca^{2+}	Brick-red
Sr^{2+}	Crimson
Ba^{2+}	Apple green
Ra^{2+}	Crimson red

Be & Mg (due to high ionization energy) do not impart any characteristic colour to flame.

GROUP 13

ATOMIC RADIUS (pm)

B(88) < Ga(135) < Al(143) < In(167) < Tl(170)

IONIC RADIUS (+3 state: pm)

B^{3+} (27) < Al^{3+} (53.5) < Ga^{3+} (62) < In^{3+} (80) < Tl^{3+} (88.5)

FIRST IONISATION ENERGY (kJ/mol)

B(801) < Tl(589) < Ga(579) < Al(577) < In(558)

SECOND IONISATION ENERGY (kJ/mol)

B(2427) < Ga(1979) < Tl(1971) < In(1820) < Al(1816)

THIRD IONISATION ENERGY (kJ/mol)

B(3659) < Ga(2962) < Tl(2877) < Al(2744) < In(2704)

ELECTRONEGATIVITY

B(2) > Tl(1.8) < In(1.7) < Ga(1.6) < Al(1.5)

DENSITY (gm/cm^3)

B(2.35) < Al(2.70) < Ga(5.9) < In(7.31) < Tl(11.85)

MELTING POINT (K)

B(2453) > Al(933) > Tl(575) > In(430) > Ga(303)

BOILING POINT (K)

B(3923) > Al(2740) > Ga(2676) > In(2353) > Tl(1730)

NOTE: Maximum oxidation state shown by a p block element is number of electrons in valence shell. Out of two oxidation states +3 and +1, lower oxidation state +1 becomes more and more stable as we move down the group due to inert pair effect. For Tl +1 state is more stable than +3.

GROUP 14

ATOMIC RADIUS (pm)

C(77) < Si(118) < Ge(122) < Sn(140) < Pb(146)

FIRST IONISATION ENERGY (kJ/mol)

C(1086) > Si(786) > Ge(761) > Pb(715) > Sn(708)

SECOND IONISATION ENERGY (kJ/mol)

C(2352) > Si(1577) > Ge(1537) > Pb(1450) > Sn(1411)

THIRD IONISATION ENERGY (kJ/mol)

C(4620) > Ge(3300) > Si(3228) > Pb(3081) > Sn(2942)

FOURTH IONISATION ENERGY (kJ/mol)

C(6220) > Ge(4409) > Si(4354) > Pb(4082) > Sn(3929)

ELECTRONEGATIVITY

C(2.5) > Sn(1.9) > Si(1.8) ≃ Ge(1.8) ≃ Pb(1.8)

DENSITY (gm/cm^3)

Pb(11.34) > Sn(7.26) > Ge(5.32) > C(3.51) > Si(2.34)

MELTING POINT (K)

C(4373) > Si(1693) > Ge(1218) > Pb(600) > Sn(505)

BOILING POINT (K)

C(~) > Si(3550) > Ge(3123) > Sn(2896) > Pb(2024)

NOTE: Out of two oxidation states +4 and +2, lower oxidation state +2 becomes more and more stable as we move down the group due to inert pair effect. For Pb +2 state is more stable than +4.

GROUP 15 (PNICTOGENS)

ATOMIC RADIUS (pm)

N(70) < P(110) < As(121) < Sb(141) < Bi(148)

IONIC RADIUS (-3 state: pm)

N^{3-}(171) < P^{3-}(212) < As^{3-}(222)

FIRST IONISATION ENERGY (kJ/mol)

N(1402) > P(1012) > As(947) > Sb(834) > Bi(703)

SECOND IONISATION ENERGY (kJ/mol)

N(2856) > P(1903) > As(1798) > Bi(1610) > Sb(1595)

THIRD IONISATION ENERGY (kJ/mol)

N(4577) > P(2910) > As(2736) > Bi(2466) > Sb(2443)

ELECTRONEGATIVITY

N(3) > P(2.1) > As(2) > Sb(1.9) ≃ Bi(1.9)

DENSITY (gm/cm^3)

Bi(9.808) > Sb(6.697) > As(5.778) > P(1.823) > N(0.879)

MELTING POINT (K)

As(1089) > Sb(904) > Bi(544) > P(317) > N(63)

BOILING POINT (K)

Sb(1860) > Bi(1837) > As(888) > P(554) > N(77.2)

NOTE: Out of two oxidation states +5 and +3, lower oxidation state +3 becomes more and more stable as we move down the group due to inert pair effect. For Bi +3 state is more stable than +5.

GROUP 16 (CHALCOGENS)

ATOMIC RADIUS (pm)

O(66) < S(104) < Se(117) < Te(137) < Po(146)

IONIC RADIUS (-2 state: pm)

O^{2-} (140) < S^{2-} (184) < Se^{2-} (198) < Te^{2-} (221) < Po^{2-} (230)

ELECTRON GAIN ENTHALPY (kJ/mol)

S(-200) > Se(-195) > Te(-190) > Po(-174) > O(-141)

FIRST IONISATION ENERGY (kJ/mol)

O(1314) > S(1000) > Se(941) > Te(869) > Po(813)

ELECTRONEGATIVITY

O(3.5) > S(2.58) > Se(2.55) > Te(2.01) > Bi(1.76)

DENSITY (gm/cm^3)

Po(~) > Te(6.25) > Se(4.19) > S(2.06) > O(1.32)

MELTING POINT (K)

Te(725) > Po(520) > Se(490) > S(393) > O(55)

BOILING POINT (K)

Te(1260) > Po(1235) > Se(958) > S(718) > O(90)

GROUP 17 (HALOGENS)

ATOMIC RADIUS (pm)

F(64) < Cl(99) < Br(114) < I(133) < At(~)

IONIC RADIUS (-1 state: pm)

F^-(133) < Cl^-(184) < Br^-(196) < I^-(220)

ELECTRON GAIN ENTHALPY (kJ/mol)

Cl(-349) > F(-333) > Br(-325) > I(-296)

IONISATION ENERGY (kJ/mol)

F(1680) > Cl(1256) > Br(1142) > I(1008)

ELECTRONEGATIVITY

F(4) > Cl(3.2) > Br(3) > I(2.7) > At(2.2)

DENSITY (gm/cm^3)

I(4.92) > Br(3.19) > F(1.5) > Cl(1.66)

MELTING POINT (K)

F(54.4) < Cl(172) < Br(265.8) < I(386.6)

BOILING POINT (K)

F(84.9) < Cl(239) < Br(332.5) < I(458.2)

BOND ENERGY (kJ/mol)

Cl-Cl(242.6) > Br-Br(192.8) > F-F(158.8) > I-I(151.1)

OXIDISING NATURE (SRP: Volts)

F_2 (2.87) > Cl_2 (1.36) > Br_2 (1.09) > I_2 (0.54)

GROUP 18 (NOBLE GASES)

ATOMIC RADIUS (pm)

He(120) < Ne(160) < Ar(190) < Kr(200) < Xe(220)

ELECTRON GAIN ENTHALPY (kJ/mol)

He(48) > Ne(116) > Ar(96) ≃ Kr(96) > Xe(77)

IONISATION ENERGY (kJ/mol)

He(2372) > Ne(2080) > Ar(1520) > Kr(1351) > Xe(1170)

DENSITY (gm/cm^3)

$He(1.8\times10^{-4}) < Ne(9\times10^{-4}) < Ar(1.8\times10^{-3})$

$< Kr(3.7\times10^{-3}) < Xe(5.9\times10^{-3})$

MELTING POINT (K)

He(~) < Ne(24.6) < Ar(83.8) < Kr(115.9) < Xe(161.3)

BOILING POINT (K)

He(4.2) < Ne(27.1) < Ar(87.2) < Kr(119.7) < Xe(165)

3d SERIES (TRNASITION ELEMENSTS)

ATOMIC RADIUS (pm)

Sc(144) > Ti(132) > V(122) > Cr(118) ≃ Mn(117)

≃ Fe(117) ≃ Co(116) ≃ Ni(115) ≃ Cu(117) < Zn(125)

IONISATION ENTHALPY (kJ/mol) Irregular trend

Sc(631) < Ti(656) > V(650) < Cr(653) < Mn(717)

< Fe(762) > Co(758) > Ni(736) < Cu(745) < Zn(906)

DENSITY (gm/ml)

Sc(3.43) < Ti(4.1) < V(6.07) < Cr(7.19) < Mn(7.21)

< Fe(7.8) < Co(8.7) < Ni(8.9) ≃ Cu(8.9) > Zn(7.1)

Anomalous Electronic Configuration

Cr: $4s^1 3d^5$, Cu: $4s^1 3d^{10}$

4d SERIES (TRNASITION ELEMENSTS)

ATOMIC RADIUS (pm)

$Y(162) > Zr(145) > Nb(134) > Mo(130) \simeq Tc(128)$

$\simeq Ru(125) \simeq Rh(125) \simeq Pd(128) < Ag(134) < Cd(148)$

Anomalous Electronic Configuration

$Nb: 5s^1 4d^4$, $Mo: 5s^1 4d^5$, $Tc: 5s^1 4d^6$,

$Ru: 5s^1 4d^7$, $Rh: 5s^1 4d^8$, $Pd: 5s^0 4d^{10}$, $Ag: 5s^1 4d^{10}$

NOTE: Zr-Hf, Nb-Ta, Mo-W, Tc-Re, Ru-Os, Rh-Ir etc. have almost same sizes so have similar properties and are called chemical twins.

5d SERIES (TRNASITION ELEMENSTS)

ATOMIC RADIUS (pm)

$La(168) > Hf(144) > Ta(134) > W(130) \simeq Re(128)$

$\simeq Os(126) \simeq Ir(126) < Pt(129) < Au(134) < Hg(149)$

Anomalous Electronic Configuration

$Pt: 6s^1 5d^9$, $Au: 6s^1 5d^{10}$

NOTE: Though copper, silver and gold have completely filled sets of d-orbitals yet they are considered as transition metals because these metals in their common oxidation states have

incompletely filled d-orbitals e.g. Cu^{2+} has $3d^9$ and Au^{3+} has $5d^8$ configuration.

Zinc, cadmium and mercury are generally not considered as transition metals because these elements in their most common oxidation state of +2 have completely filled d-orbitals.

Because of small size of their atoms and strong metallic bonding the density and hardness of transition elements are high.

f-block
(INNER TRNASITION ELEMENSTS)

Lanthanides

$[Xe]\ 4f^{1-14}5d^{0-1}6s^2$

Actinides

$[Rn]\ 5f^{1-14}6d^{0-1}7s^2$

NOTE: Lanthanides show only one stable oxidation state, which is not in the case of actinides. The typical oxidation state of lanthanides is +3. Some elements show +2 and +4 also, when they lead to

(1) a noble gas configuration e.g. $Ce^{4+}\left(f^0\right)$, (Ce(IV) salts are good oxidising agents)

(2) a half filled f shell e.g. $Eu^{2+}\left(f^7\right)$(Eu(II) salts are good reducing agents)

(3) a completely filled f shell e.g. $Yb^{2+}\left(f^{14}\right)$

As the size of the lanthanide ions decreases from La^{+3} to Lu^{+3}, the covalent character of the hydroxides increases and hence the basic strength decreases. Thus $La(OH)_3$ is most basic whereas $Lu(OH)_3$ is least basic.