

The Transition Metals

IUPAC – "An element whose atom has an incomplete d sub-shell, or which can give rise to cations with an incomplete d sub-shell." Group 12 elements are excluded by this definition.

Early		Middle			Late				
3	4	5	6	7	8	9	10	11	
21 Sc Scandium 44.955912	22 Ti Titanium 47.867	23 V Vanadium 50.9415	24 Cr Chromium 51.9981	25 Mn Manganese 54.938045	26 Fe Iron 55.845	27 Co Cobalt 58.933195	28 Ni Nickel 58.6934	29 Cu Copper 63.546	
39 Y Yttrium 88.90585	40 Zr Zirconium 91.224	41 Nb Niobium 92.90638	42 Mo Molybdenum 95.96	43 Tc Technetium (97.9072)	44 Ru Ruthenium 101.07	45 Rh Rhodium 102.90550	46 Pd Palladium 106.42	47 Ag Silver 107.8682	
57–71	72 Hf Hafnium 178.49	73 Ta Tantalum 180.94788	74 W Tungsten 183.84	75 Re Rhenium 186.207	76 Os Osmium 190.23	77 Ir Iridium 192.217	78 Pt Platinum 195.084	79 Au Gold 196.966569	
89–103	104 Rf Rutherfordium (261)	105 Db Dubnium (262)	106 Sg Seaborgium (266)	107 Bh Bohrium (264)	108 Hs Hassium (277)	109 Mt Meitnerium (268)	110 Ds Darmstadtium (271)	111 Rg Roentgenium (272)	

Characteristic properties

- formation of compounds whose color is due to $d - d$ electronic transitions
- formation of compounds in many oxidation states, due to relatively low reactivity of unpaired d electrons
- formation of many paramagnetic compounds due to unpaired d electrons

The Early Transition Metals

Early

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│ 3 │ │ 4 │
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21 Sc Scandium 44.955912	22 Ti Titanium 47.867
39 Y Yttrium 88.90585	40 Zr Zirconium 91.224
57–71	72 Hf Hafnium 178.49
89–103	104 Rf Rutherfordium (261)

- Strongly electrophilic and oxophilic
 - Few redox reactions (except Ti)
 - Nearly always < 18 electrons
 - Few *d*-electrons
 - Polar and very reactive M–C bonds
 - Preference for "hard" σ -donors (N/O/F)
 - Weak complexation of π -acceptors (olefins)
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- Highly useful in polymerizations, we will probably not discuss much

The Middle Transition Metals

Middle

5 6 7

23 V Vanadium 50.9415	24 Cr Chromium 51.9961	25 Mn Manganese 54.938045
41 Nb Niobium 92.90638	42 Mo Molybdenum 95.96	43 Tc Technetium (97.9072)
73 Ta Tantalum 180.94788	74 W Tungsten 183.84	75 Re Rhenium 186.207
105 Db Dubnium (262)	106 Sg Seaborgium (266)	107 Bh Bohrium (264)

- Many accessible oxidation states
- Mostly 18 electrons
- Ligands strongly bound
- Strong, not very reactive M–C bonds
- Preference σ -donor/ π -acceptor combinations (e.g., CO)

The Late Transition Metals

- Many accessible oxidation states
- Mostly 18 or 16 electrons
 - 16 common for square-planar complexes
- Easy ligand association/dissociation
- Weak, not very reactive M–C bonds
- Weaker, reactive M–O/M–N bonds
- Preference σ -donor/weak π -acceptor combinations (e.g., phosphines)

Late

Late			
8	9	10	11
26 Fe Iron 55.845	27 Co Cobalt 58.933195	28 Ni Nickel 58.6934	29 Cu Copper 63.546
44 Ru Ruthenium 101.07	45 Rh Rhodium 102.90550	46 Pd Palladium 106.42	47 Ag Silver 107.8682
76 Os Osmium 190.23	77 Ir Iridium 192.217	78 Pt Platinum 195.084	79 Au Gold 196.966569
108 Hs Hassium (277)	109 Mt Meitnerium (268)	110 Ds Darmstadtium (271)	111 Rg Roentgenium (272)