



**MATERIALS SCIENCE  
& ENGINEERING**  
TEXAS A&M UNIVERSITY

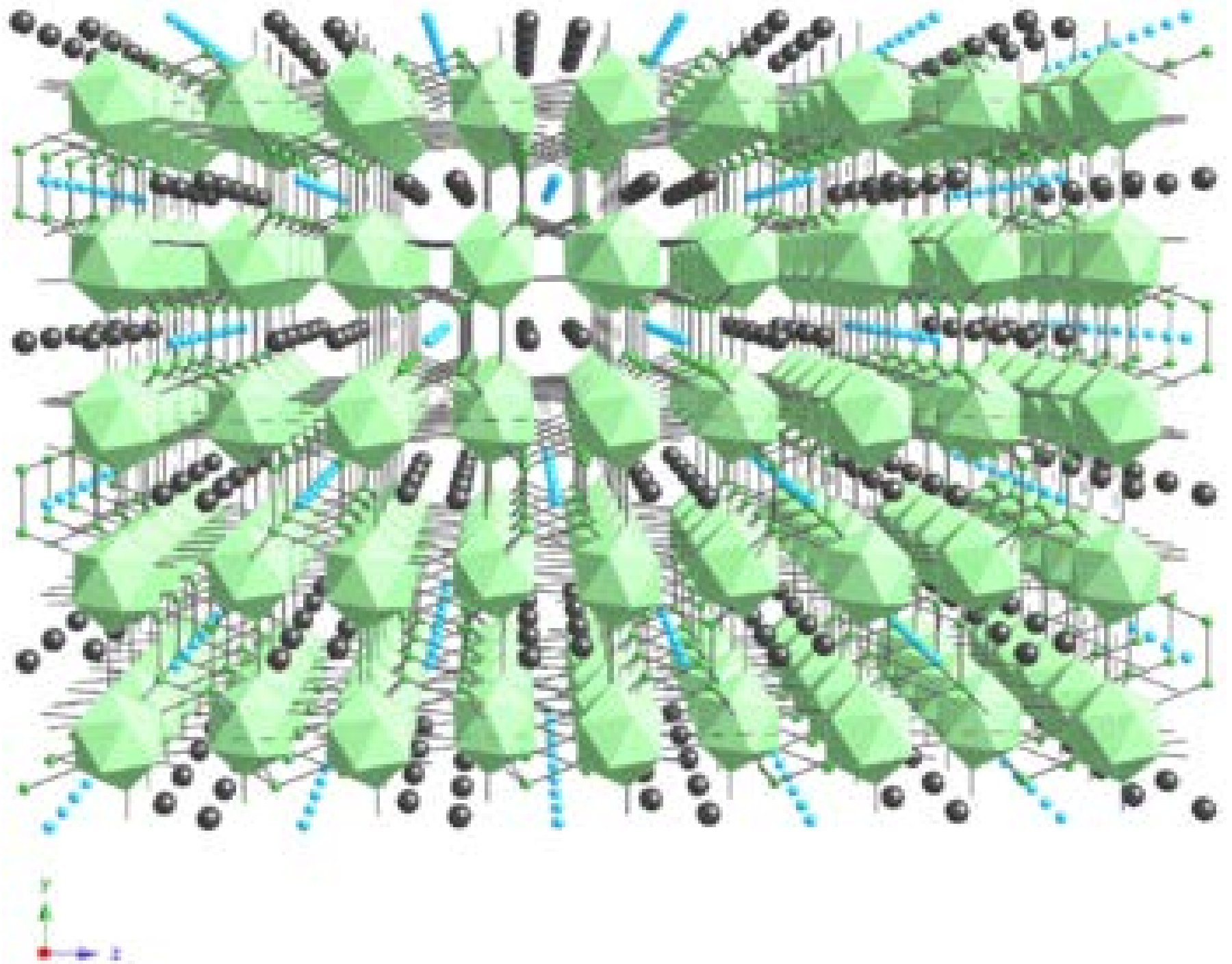
# Introduction to Materials Science & Engineering

## Atomic Bonding

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# Ionic Bonding

Group	1 1A	2 2A											13 3A	14 4A	15 5A	16 6A	17 7A	18 8A						
1	1 H Hydrogen 1.0078																		2 He Helium 4.0026					
2	3 Li Lithium 6.938	4 Be Beryllium 9.0122												6 C Carbon 12.009	7 N Nitrogen 14.006	8 O Oxygen 15.999	9 F Fluorine 18.998	10 Ne Neon 20.180						
3	11 Na Sodium 22.990	12 Mg Magnesium 24.305	13 Al Aluminum 26.982	14 Si Silicon 28.084	15 P Phosphorus 30.974	16 S Sulfur 32.059	17 Cl Chlorine 35.446	18 Ar Argon 39.948																
4	19 K Potassium 39.098	20 Ca Calcium 40.078	21 Sc Scandium 44.956	22 Ti Titanium 47.867	23 V Vanadium 50.942	24 Cr Chromium 51.996	25 Mn Manganese 54.938	26 Fe Iron 55.845	27 Co Cobalt 58.933	28 Ni Nickel 58.693	29 Cu Copper 63.546	30 Zn Zinc 65.38	31 Ga Gallium 69.723	32 Ge Germanium 72.63	33 As Arsenic 74.922	34 Se Selenium 78.96	35 Br Bromine 79.904	36 Kr Krypton 83.798						
5	37 Rb Rubidium 85.468	38 Sr Strontium 87.62	39 Y Yttrium 88.906	40 Zr Zirconium 91.224	41 Nb Niobium 92.906	42 Mo Molybdenum 95.96	43 Tc Technetium 98.9062	44 Ru Ruthenium 101.07	45 Rh Rhodium 101.91	46 Pd Palladium 106.42	47 Ag Silver 107.87	48 Cd Cadmium 112.41	49 In Indium 114.82	50 Sn Tin 118.71	51 Sb Antimony 121.76	52 Te Tellurium 127.60	53 I Iodine 126.90	54 Xe Xenon 131.29						
6	55 Cs Cesium 132.91	56 Ba Barium 137.33		72 Hf Hafnium 178.49	73 Ta Tantalum 180.95	74 W Tungsten 183.84	75 Re Rhenium 186.21	76 Os Osmium 190.23	77 Ir Iridium 192.22	78 Pt Platinum 195.08	79 Au Gold 196.97	80 Hg Mercury 200.59	81 Tl Thallium 204.38	82 Pb Lead 207.2	83 Bi Bismuth 208.98	84 Po Polonium (209)	85 At Astatine (210)	86 Rn Radon (222)						
7	87 Fr Francium (223)	88 Ra Radium (226)		104 Rf Rutherfordium (261)	105 Db Dubnium (262)	106 Sg Seaborgium (266)	107 Bh Bohrium (264)	108 Hs Hassium (269)	109 Mt Meitnerium (268)	110 Ds Darmstadtium (268)	111 Rg Roentgenium (268)	112 Cn Copernicium (268)	113 Uut Ununtrium (268)	114 Fl Flerovium (268)	115 Uup Ununpentium (268)	116 Lv Livermorium (268)	117 Uus Ununseptium (268)	118 Uuo Ununoctium (268)						
			57 La Lanthanum 138.91	58 Ce Cerium 140.12	59 Pr Praseodymium 140.91	60 Nd Neodymium 144.24	61 Pm Promethium (145)	62 Sm Samarium 150.36	63 Eu Europium 151.96	64 Gd Gadolinium 157.25	65 Tb Terbium 158.93	66 Dy Dysprosium 162.50	67 Ho Holmium 164.93	68 Er Erbium 167.26	69 Tm Thulium 168.93	70 Yb Ytterbium 173.04	71 Lu Lutetium 174.97							
			89 Ac Actinium (227)	90 Th Thorium 232.04	91 Pa Protactinium 231.04	92 U Uranium 238.03	93 Np Neptunium (237)	94 Pu Plutonium (244)	95 Am Americium (243)	96 Cm Curium (247)	97 Bk Berkelium (247)	98 Cf Californium (251)	99 Es Einsteinium (252)	100 Fm Fermium (257)	101 Md Mendelevium (258)	102 No Nobelium (259)	103 Lr Lawrencium (262)							

11 — Atomic number  
 Na — Element symbol  
 Sodium — Element name  
 22.990 — Atomic weight

- Alkali metals
- Alkaline earth metals
- Lanthanides
- Actinides
- Transition metals
- Unknown properties
- Post-transition metals
- Metalloids
- Other nonmetals
- Halogens
- Noble gases

# Metallic Bonding

Group 1 1A 2 2A 13 14 15 16 17 18 8A

1 H Hydrogen 1.0078 2 He Helium 4.0026

2 Li Lithium 6.938 Be Beryllium 9.0122 3 B Boron 10.806 4 C Carbon 12.009 5 N Nitrogen 14.006 6 O Oxygen 15.999 7 F Fluorine 18.998 8 Ne Neon 20.180

3 Na Sodium 22.990 4 Mg Magnesium 24.305 5 Al Aluminum 26.982 6 Si Silicon 28.084 7 P Phosphorus 30.974 8 S Sulfur 32.059 9 Cl Chlorine 35.446 10 Ar Argon 39.948

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5 Rb Rubidium 85.468 6 Sr Strontium 87.62 7 Y Yttrium 88.906 8 Zr Zirconium 91.224 9 Nb Niobium 92.906 10 Mo Molybdenum 95.96 11 Tc Technetium 98.9062 12 Ru Ruthenium 101.07 13 Rh Rhodium 101.91 14 Pd Palladium 106.42 15 Ag Silver 107.87 16 Cd Cadmium 112.41 17 In Indium 114.82 18 Sn Tin 118.71 19 Sb Antimony 121.76 20 Te Tellurium 127.60 21 I Iodine 126.90 22 Xe Xenon 131.29

6 Cs Cesium 132.91 7 Ba Barium 137.33 8 Hf Hafnium 178.49 9 Ta Tantalum 180.95 10 W Tungsten 183.84 11 Re Rhenium 186.21 12 Os Osmium 190.23 13 Ir Iridium 192.22 14 Pt Platinum 195.08 15 Au Gold 196.97 16 Hg Mercury 200.59 17 Tl Thallium 204.38 18 Pb Lead 207.2 19 Bi Bismuth 208.98 20 Po Polonium (209) 21 At Astatine (210) 22 Rn Radon (222)

7 Fr Francium (223) 8 Ra Radium (226) 9 Rf Rutherfordium (261) 10 Db Dubnium (262) 11 Sg Seaborgium (266) 12 Bh Bohrium (264) 13 Hs Hassium (269) 14 Mt Meitnerium (268) 15 Ds Darmstadtium (268) 16 Rg Roentgenium (268) 17 Cn Copernicium (284) 18 Uut Ununtrium (268) 19 Fl Flerovium (268) 20 Uup Ununpentium (268) 21 Lv Livermorium (268) 22 Uus Ununseptium (268) 23 Uuo Ununoctium (268)

89 La Lanthanum 138.91 90 Ce Cerium 140.12 91 Pr Praseodymium 140.91 92 Nd Neodymium 144.24 93 Pm Promethium (145) 94 Sm Samarium 150.36 95 Eu Europium 151.96 96 Gd Gadolinium 157.25 97 Tb Terbium 158.93 98 Dy Dysprosium 162.50 99 Ho Holmium 164.93 100 Er Erbium 167.26 101 Tm Thulium 168.93 102 Yb Ytterbium 173.04 103 Lu Lutetium 174.97

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11 Atomic number  
Na Element symbol  
Sodium Element name  
22.990 Atomic weight

Alkali metals  
Alkaline earth metals  
Lanthanides  
Actinides  
Transition metals  
Unknown properties

Post-transition metals  
Metalloids  
Other nonmetals  
Halogens  
Noble gases

Period

Lanthanides

Actinides

# Covalent Bonding

**Legend:**

- Alkali metals (Yellow)
- Alkaline earth metals (Light blue)
- Lanthanides (Dark blue)
- Actinides (Red)
- Transition metals (Green)
- Unknown properties (White)
- Post-transition metals (Grey)
- Metalloids (Light purple)
- Other nonmetals (Light blue)
- Halogens (Cyan)
- Noble gases (Orange)

**Element Information Legend:**

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	1A	2A	3A	4A	5A	6A	7A	8A	9A	10A	11A	12A	13A	14A	15A	16A	17A	18A
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# Secondary Bonding

# Bonding Energy

Ionic

Covalent

Metallic

- Primary Bonding:
  - Covalent
  - Ionic
  - Metallic
- Secondary/Van der Waals Bonding:
  - Induced dipole/induced dipole
  - Permanent/induced dipole
  - Permanent/permanent dipole
  - H-bonding
- Bonding can be gradational!