



# Manufacturing Technology Materials and Introduction to Manufacturing

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Level 4 20 credits

JACS CODE J511

# Materials Science

## ► What is materials science?

“Materials Science is an interdisciplinary subject, spanning the physics and chemistry of matter, engineering applications and industrial manufacturing processes.”

University of Oxford

This diverse programme subject had its foundations in physics and chemistry and covers the mechanical, electrical, magnetic and optical properties of materials, and the design, manufacture and applications of metals, alloys, ceramics, polymers, composites and biomaterials.

# Elements are Materials too!

The Periodic Table puts elements in order of the structure of their atoms (how many protons they have and how many electrons they have in their outer shell) They are listed in the order of their atomic number, which is the number of protons in each atom.

## Periodic Table of Elements

| 1                                 | 2                                | 3                                 | 4                                   | 5                                 | 6                                | 7                                   | 8                               | 9                                | 10                                 | 11                                | 12                              | 13                                | 14                                 | 15                                 | 16                                | 17                                 | 18                                |
|-----------------------------------|----------------------------------|-----------------------------------|-------------------------------------|-----------------------------------|----------------------------------|-------------------------------------|---------------------------------|----------------------------------|------------------------------------|-----------------------------------|---------------------------------|-----------------------------------|------------------------------------|------------------------------------|-----------------------------------|------------------------------------|-----------------------------------|
| 1<br>H<br>Hydrogen<br>1.00794     | 2<br>He<br>Helium<br>4.002602    |                                   |                                     |                                   |                                  |                                     |                                 |                                  |                                    |                                   |                                 | 3<br>B<br>Boron<br>10.811         | 4<br>C<br>Carbon<br>12.011         | 5<br>N<br>Nitrogen<br>14.007       | 6<br>O<br>Oxygen<br>15.9994       | 7<br>F<br>Fluorine<br>18.9984032   | 8<br>Ne<br>Neon<br>20.1797        |
| 3<br>Li<br>Lithium<br>6.941       | 4<br>Be<br>Beryllium<br>9.012182 |                                   |                                     |                                   |                                  |                                     |                                 |                                  |                                    |                                   |                                 | 9<br>Al<br>Aluminum<br>26.9815386 | 10<br>Si<br>Silicon<br>28.0855     | 11<br>P<br>Phosphorus<br>30.973762 | 12<br>S<br>Sulfur<br>32.06        | 13<br>Cl<br>Chlorine<br>35.45      | 14<br>Ar<br>Argon<br>39.948       |
| 11<br>Na<br>Sodium<br>22.98976928 | 12<br>Mg<br>Magnesium<br>24.3050 |                                   |                                     |                                   |                                  |                                     |                                 |                                  |                                    |                                   |                                 | 15<br>Ga<br>Gallium<br>69.723     | 16<br>Ge<br>Germanium<br>72.64     | 17<br>As<br>Arsenic<br>74.921595   | 18<br>Se<br>Selenium<br>78.96     | 19<br>Br<br>Bromine<br>79.904      | 20<br>Kr<br>Krypton<br>83.798     |
| 19<br>K<br>Potassium<br>39.0983   | 20<br>Ca<br>Calcium<br>40.078    | 21<br>Sc<br>Scandium<br>44.955912 | 22<br>Ti<br>Titanium<br>47.88       | 23<br>V<br>Vanadium<br>50.9415    | 24<br>Cr<br>Chromium<br>51.9961  | 25<br>Mn<br>Manganese<br>54.938045  | 26<br>Fe<br>Iron<br>55.845      | 27<br>Co<br>Cobalt<br>58.933195  | 28<br>Ni<br>Nickel<br>58.6934      | 29<br>Cu<br>Copper<br>63.546      | 30<br>Zn<br>Zinc<br>65.38       | 31<br>Ga<br>Gallium<br>69.723     | 32<br>Ge<br>Germanium<br>72.64     | 33<br>As<br>Arsenic<br>74.921595   | 34<br>Se<br>Selenium<br>78.96     | 35<br>Br<br>Bromine<br>79.904      | 36<br>Kr<br>Krypton<br>83.798     |
| 37<br>Rb<br>Rubidium<br>85.4678   | 38<br>Sr<br>Strontium<br>87.62   | 39<br>Y<br>Yttrium<br>88.90585    | 40<br>Zr<br>Zirconium<br>91.224     | 41<br>Nb<br>Niobium<br>92.90638   | 42<br>Mo<br>Molybdenum<br>95.94  | 43<br>Tc<br>Technetium<br>(97.9072) | 44<br>Ru<br>Ruthenium<br>101.07 | 45<br>Rh<br>Rhodium<br>102.90550 | 46<br>Pd<br>Palladium<br>106.42    | 47<br>Ag<br>Silver<br>107.8682    | 48<br>Cd<br>Cadmium<br>112.411  | 49<br>In<br>Indium<br>114.818     | 50<br>Sn<br>Tin<br>118.710         | 51<br>Sb<br>Antimony<br>121.757    | 52<br>Te<br>Tellurium<br>127.6    | 53<br>I<br>Iodine<br>126.90447     | 54<br>Xe<br>Xenon<br>131.29       |
| 55<br>Cs<br>Cesium<br>132.9054519 | 56<br>Ba<br>Barium<br>137.327    | 57-71<br>Lanthanoids              | 72<br>Hf<br>Hafnium<br>178.49       | 73<br>Ta<br>Tantalum<br>180.94788 | 74<br>W<br>Tungsten<br>183.84    | 75<br>Re<br>Rhenium<br>186.207      | 76<br>Os<br>Osmium<br>190.23    | 77<br>Ir<br>Iridium<br>192.222   | 78<br>Pt<br>Platinum<br>195.084    | 79<br>Au<br>Gold<br>196.966569    | 80<br>Hg<br>Mercury<br>200.59   | 81<br>Tl<br>Thallium<br>204.3833  | 82<br>Pb<br>Lead<br>207.2          | 83<br>Bi<br>Bismuth<br>208.98040   | 84<br>Po<br>Polonium<br>(209)     | 85<br>At<br>Astatine<br>(210)      | 86<br>Rn<br>Radon<br>(222)        |
| 87<br>Fr<br>Francium<br>(223)     | 88<br>Ra<br>Radium<br>(226)      | 89-103<br>Actinoids               | 104<br>Rf<br>Rutherfordium<br>(261) | 105<br>Db<br>Dubnium<br>(262)     | 106<br>Sg<br>Seaborgium<br>(266) | 107<br>Bh<br>Bohrium<br>(264)       | 108<br>Hs<br>Hassium<br>(277)   | 109<br>Mt<br>Meitnerium<br>(268) | 110<br>Ds<br>Darmstadtium<br>(271) | 111<br>Rg<br>Roentgenium<br>(272) | 112<br>Uub<br>Ununbium<br>(285) | 113<br>Uut<br>Ununtrium<br>(284)  | 114<br>Uuq<br>Ununquadium<br>(289) | 115<br>Uup<br>Ununpentium<br>(288) | 116<br>Uuh<br>Ununhexium<br>(289) | 117<br>Uus<br>Ununseptium<br>(294) | 118<br>Uuo<br>Ununoctium<br>(294) |

For elements with no stable isotopes, the mass number of the isotope with the longest half-life is in parentheses.

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|                                    |                                  |                                       |                                  |                                 |                                |                                 |                                  |                                  |                                   |                                  |                               |                                   |                                  |                                  |
|------------------------------------|----------------------------------|---------------------------------------|----------------------------------|---------------------------------|--------------------------------|---------------------------------|----------------------------------|----------------------------------|-----------------------------------|----------------------------------|-------------------------------|-----------------------------------|----------------------------------|----------------------------------|
| 57<br>La<br>Lanthanum<br>138.90547 | 58<br>Ce<br>Cerium<br>140.116    | 59<br>Pr<br>Praseodymium<br>140.90768 | 60<br>Nd<br>Neodymium<br>144.242 | 61<br>Pm<br>Promethium<br>(145) | 62<br>Sm<br>Samarium<br>150.36 | 63<br>Eu<br>Europium<br>151.964 | 64<br>Gd<br>Gadolinium<br>157.25 | 65<br>Tb<br>Terbium<br>158.92535 | 66<br>Dy<br>Dysprosium<br>162.500 | 67<br>Ho<br>Holmium<br>164.93032 | 68<br>Er<br>Erbium<br>167.259 | 69<br>Tm<br>Thulium<br>168.93421  | 70<br>Yb<br>Ytterbium<br>173.054 | 71<br>Lu<br>Lutetium<br>174.967  |
| 89<br>Ac<br>Actinium<br>(227)      | 90<br>Th<br>Thorium<br>232.03806 | 91<br>Pa<br>Protactinium<br>231.03688 | 92<br>U<br>Uranium<br>238.02891  | 93<br>Np<br>Neptunium<br>(237)  | 94<br>Pu<br>Plutonium<br>(244) | 95<br>Am<br>Americium<br>(243)  | 96<br>Cm<br>Curium<br>(247)      | 97<br>Bk<br>Berkelium<br>(247)   | 98<br>Cf<br>Californium<br>(251)  | 99<br>Es<br>Einsteinium<br>(252) | 100<br>Fm<br>Fermium<br>(257) | 101<br>Md<br>Mendelevium<br>(258) | 102<br>No<br>Nobelium<br>(259)   | 103<br>Lr<br>Lawrencium<br>(262) |

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# Periodic Table of Elements

|   | 1                                                                    | 2                                                                                                                                                                                                                                                                                                                                                                                                              | 3                                                                    | 4                                                                  | 5                                                                      | 6                                                                    | 7                                                                      | 8                                                                  | 9                                                                   | 10                                                                  | 11                                                                    | 12                                                                   | 13                                                                 | 14                                                                  | 15                                                                    | 16                                                                    | 17                                                                   | 18                                                                    |                                                                      |
|---|----------------------------------------------------------------------|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|----------------------------------------------------------------------|--------------------------------------------------------------------|------------------------------------------------------------------------|----------------------------------------------------------------------|------------------------------------------------------------------------|--------------------------------------------------------------------|---------------------------------------------------------------------|---------------------------------------------------------------------|-----------------------------------------------------------------------|----------------------------------------------------------------------|--------------------------------------------------------------------|---------------------------------------------------------------------|-----------------------------------------------------------------------|-----------------------------------------------------------------------|----------------------------------------------------------------------|-----------------------------------------------------------------------|----------------------------------------------------------------------|
| 1 | <div>1</div> <div>H</div> <div>Hydrogen</div> <div>1.00794</div>     | <div>Atomic #</div> <div>Symbol</div> <div>Name</div> <div>Atomic Mass</div> <div>C Solid</div> <div>Hg Liquid</div> <div>H Gas</div> <div>Rf Unknown</div> <div>Metals</div> <div>Alkali metals</div> <div>Alkaline earth metals</div> <div>Lanthanoids</div> <div>Actinoids</div> <div>Transition metals</div> <div>Poor metals</div> <div>Nonmetals</div> <div>Other nonmetals</div> <div>Noble gases</div> |                                                                      |                                                                    |                                                                        |                                                                      |                                                                        |                                                                    |                                                                     |                                                                     |                                                                       |                                                                      |                                                                    |                                                                     |                                                                       |                                                                       |                                                                      | <div>2</div> <div>He</div> <div>Helium</div> <div>4.002602</div>      |                                                                      |
| 2 | <div>3</div> <div>Li</div> <div>Lithium</div> <div>6.941</div>       | <div>4</div> <div>Be</div> <div>Beryllium</div> <div>9.012182</div>                                                                                                                                                                                                                                                                                                                                            |                                                                      |                                                                    |                                                                        |                                                                      |                                                                        |                                                                    |                                                                     |                                                                     |                                                                       |                                                                      |                                                                    |                                                                     |                                                                       |                                                                       |                                                                      |                                                                       | <div>10</div> <div>Ne</div> <div>Neon</div> <div>20.1797</div>       |
| 3 | <div>11</div> <div>Na</div> <div>Sodium</div> <div>22.98976928</div> | <div>12</div> <div>Mg</div> <div>Magnesium</div> <div>24.3050</div>                                                                                                                                                                                                                                                                                                                                            |                                                                      |                                                                    |                                                                        |                                                                      |                                                                        |                                                                    |                                                                     |                                                                     |                                                                       |                                                                      |                                                                    |                                                                     |                                                                       |                                                                       |                                                                      |                                                                       | <div>18</div> <div>Ar</div> <div>Argon</div> <div>39.948</div>       |
| 4 | <div>19</div> <div>K</div> <div>Potassium</div> <div>39.0983</div>   | <div>20</div> <div>Ca</div> <div>Calcium</div> <div>40.078</div>                                                                                                                                                                                                                                                                                                                                               | <div>21</div> <div>Sc</div> <div>Scandium</div> <div>44.955912</div> | <div>22</div> <div>Ti</div> <div>Titanium</div> <div>47.887</div>  | <div>23</div> <div>V</div> <div>Vanadium</div> <div>50.9415</div>      | <div>24</div> <div>Cr</div> <div>Chromium</div> <div>51.9961</div>   | <div>25</div> <div>Mn</div> <div>Manganese</div> <div>54.938045</div>  | <div>26</div> <div>Fe</div> <div>Iron</div> <div>55.845</div>      | <div>27</div> <div>Co</div> <div>Cobalt</div> <div>58.933195</div>  | <div>28</div> <div>Ni</div> <div>Nickel</div> <div>58.6934</div>    | <div>29</div> <div>Cu</div> <div>Copper</div> <div>63.546</div>       | <div>30</div> <div>Zn</div> <div>Zinc</div> <div>65.38</div>         | <div>31</div> <div>Ga</div> <div>Gallium</div> <div>69.723</div>   | <div>32</div> <div>Ge</div> <div>Germanium</div> <div>72.64</div>   | <div>33</div> <div>As</div> <div>Arsenic</div> <div>74.92160</div>    | <div>34</div> <div>Se</div> <div>Selenium</div> <div>78.96</div>      | <div>35</div> <div>Br</div> <div>Bromine</div> <div>79.904</div>     | <div>36</div> <div>Kr</div> <div>Krypton</div> <div>83.796</div>      |                                                                      |
| 5 | <div>37</div> <div>Rb</div> <div>Rubidium</div> <div>85.4678</div>   | <div>38</div> <div>Sr</div> <div>Strontium</div> <div>87.62</div>                                                                                                                                                                                                                                                                                                                                              | <div>39</div> <div>Y</div> <div>Yttrium</div> <div>88.90585</div>    | <div>40</div> <div>Zr</div> <div>Zirconium</div> <div>91.224</div> | <div>41</div> <div>Nb</div> <div>Niobium</div> <div>92.90638</div>     | <div>42</div> <div>Mo</div> <div>Molybdenum</div> <div>95.96</div>   | <div>43</div> <div>Tc</div> <div>Technetium</div> <div>(97.9072)</div> | <div>44</div> <div>Ru</div> <div>Ruthenium</div> <div>101.07</div> | <div>45</div> <div>Rh</div> <div>Rhodium</div> <div>102.90550</div> | <div>46</div> <div>Pd</div> <div>Palladium</div> <div>106.42</div>  | <div>47</div> <div>Ag</div> <div>Silver</div> <div>107.8682</div>     | <div>48</div> <div>Cd</div> <div>Cadmium</div> <div>112.411</div>    | <div>49</div> <div>In</div> <div>Indium</div> <div>114.818</div>   | <div>50</div> <div>Sn</div> <div>Tin</div> <div>118.710</div>       | <div>51</div> <div>Sb</div> <div>Antimony</div> <div>121.760</div>    | <div>52</div> <div>Te</div> <div>Tellurium</div> <div>127.6</div>     | <div>53</div> <div>I</div> <div>Iodine</div> <div>126.90447</div>    | <div>54</div> <div>Xe</div> <div>Xenon</div> <div>131.29</div>        |                                                                      |
| 6 | <div>55</div> <div>Cs</div> <div>Cesium</div> <div>132.9054519</div> | <div>56</div> <div>Ba</div> <div>Barium</div> <div>137.327</div>                                                                                                                                                                                                                                                                                                                                               | <div>57–71</div>                                                     |                                                                    | <div>72</div> <div>Hf</div> <div>Hafnium</div> <div>178.49</div>       | <div>73</div> <div>Ta</div> <div>Tantalum</div> <div>180.94788</div> | <div>74</div> <div>W</div> <div>Tungsten</div> <div>183.84</div>       | <div>75</div> <div>Re</div> <div>Rhenium</div> <div>186.207</div>  | <div>76</div> <div>Os</div> <div>Osmium</div> <div>190.23</div>     | <div>77</div> <div>Ir</div> <div>Iridium</div> <div>192.217</div>   | <div>78</div> <div>Pt</div> <div>Platinum</div> <div>195.084</div>    | <div>79</div> <div>Au</div> <div>Gold</div> <div>196.966569</div>    | <div>80</div> <div>Hg</div> <div>Mercury</div> <div>200.59</div>   | <div>81</div> <div>Tl</div> <div>Thallium</div> <div>204.3833</div> | <div>82</div> <div>Pb</div> <div>Lead</div> <div>207.2</div>          | <div>83</div> <div>Bi</div> <div>Bismuth</div> <div>208.98040</div>   | <div>84</div> <div>Po</div> <div>Polonium</div> <div>(209)</div>     | <div>85</div> <div>At</div> <div>Astatine</div> <div>(210)</div>      | <div>86</div> <div>Rn</div> <div>Radon</div> <div>(222)</div>        |
| 7 | <div>87</div> <div>Fr</div> <div>Francium</div> <div>(223)</div>     | <div>88</div> <div>Ra</div> <div>Radium</div> <div>(226)</div>                                                                                                                                                                                                                                                                                                                                                 | <div>89–103</div>                                                    |                                                                    | <div>104</div> <div>Rf</div> <div>Rutherfordium</div> <div>(261)</div> | <div>105</div> <div>Db</div> <div>Dubnium</div> <div>(262)</div>     | <div>106</div> <div>Sg</div> <div>Seaborgium</div> <div>(266)</div>    | <div>107</div> <div>Bh</div> <div>Bohrium</div> <div>(264)</div>   | <div>108</div> <div>Hs</div> <div>Hassium</div> <div>(277)</div>    | <div>109</div> <div>Mt</div> <div>Meitnerium</div> <div>(268)</div> | <div>110</div> <div>Ds</div> <div>Darmstadtium</div> <div>(271)</div> | <div>111</div> <div>Rg</div> <div>Roentgenium</div> <div>(272)</div> | <div>112</div> <div>Uub</div> <div>Ununbium</div> <div>(285)</div> | <div>113</div> <div>Uut</div> <div>Ununtrium</div> <div>(284)</div> | <div>114</div> <div>Uuq</div> <div>Ununquadium</div> <div>(289)</div> | <div>115</div> <div>Uup</div> <div>Ununpentium</div> <div>(288)</div> | <div>116</div> <div>Uuh</div> <div>Ununhexium</div> <div>(292)</div> | <div>117</div> <div>Uus</div> <div>Ununseptium</div> <div>(294)</div> | <div>118</div> <div>Uuo</div> <div>Ununoctium</div> <div>(294)</div> |

For elements with no stable isotopes, the mass number of the isotope with the longest half-life is in parentheses.

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|                                        |                                      |                                           |                                      |                                     |                                    |                                     |                                      |                                      |                                       |                                      |                                   |                                       |                                      |                                      |
|----------------------------------------|--------------------------------------|-------------------------------------------|--------------------------------------|-------------------------------------|------------------------------------|-------------------------------------|--------------------------------------|--------------------------------------|---------------------------------------|--------------------------------------|-----------------------------------|---------------------------------------|--------------------------------------|--------------------------------------|
| 57 <b>La</b><br>Lanthanum<br>138.90547 | 58 <b>Ce</b><br>Cerium<br>140.116    | 59 <b>Pr</b><br>Praseodymium<br>140.90768 | 60 <b>Nd</b><br>Neodymium<br>144.242 | 61 <b>Pm</b><br>Promethium<br>(145) | 62 <b>Sm</b><br>Samarium<br>150.36 | 63 <b>Eu</b><br>Europium<br>151.964 | 64 <b>Gd</b><br>Gadolinium<br>157.25 | 65 <b>Tb</b><br>Terbium<br>158.92535 | 66 <b>Dy</b><br>Dysprosium<br>162.500 | 67 <b>Ho</b><br>Holmium<br>164.93032 | 68 <b>Er</b><br>Erbium<br>167.259 | 69 <b>Tm</b><br>Thulium<br>168.93421  | 70 <b>Yb</b><br>Ytterbium<br>173.054 | 71 <b>Lu</b><br>Lutetium<br>174.9668 |
| 89 <b>Ac</b><br>Actinium<br>(227)      | 90 <b>Th</b><br>Thorium<br>232.03806 | 91 <b>Pa</b><br>Protactinium<br>231.03688 | 92 <b>U</b><br>Uranium<br>238.02891  | 93 <b>Np</b><br>Neptunium<br>(237)  | 94 <b>Pu</b><br>Plutonium<br>(244) | 95 <b>Am</b><br>Americium<br>(243)  | 96 <b>Cm</b><br>Curium<br>(247)      | 97 <b>Bk</b><br>Berkelium<br>(247)   | 98 <b>Cf</b><br>Californium<br>(251)  | 99 <b>Es</b><br>Einsteinium<br>(252) | 100 <b>Fm</b><br>Fermium<br>(257) | 101 <b>Md</b><br>Mendelevium<br>(258) | 102 <b>No</b><br>Nobelium<br>(259)   | 103 <b>Lr</b><br>Lawrencium<br>(262) |

1 electron in its outer shell

Full shell

**Table 1.1 Relative Abundance of Elements in the Universe**

| Element        | Relative<br>Abundance (Si = 1) |
|----------------|--------------------------------|
| Hydrogen (H)   | 12,000                         |
| Helium (He)    | 2,800                          |
| Oxygen (O)     | 16                             |
| Nitrogen (N)   | 8                              |
| Carbon (C)     | 3                              |
| Iron (Fe)      | 2.6                            |
| Silicon (Si)   | 1                              |
| Magnesium (Mg) | 0.89                           |
| Sulfur (S)     | 0.33                           |
| Nickel (Ni)    | 0.21                           |
| Aluminum (Al)  | 0.09                           |
| Calcium (Ca)   | 0.07                           |
| Sodium (Na)    | 0.045                          |
| Chlorine (Cl)  | 0.025                          |

# Silicon

25% of the earth's crust is silicon

“Silicon is the seventh most abundant element in the universe and the second most abundant element on the planet after oxygen” - Royal Society of Chemistry

Silica - an oxide of silicon is the most common component of sand.

Silicon is a metalloid, neither metal nor non-metal. It looks metallic but unlike metal it gets better at conducting electricity with higher temperatures.

Silicon is a semiconductor

Uses - transistors, solar cells, computer chips (with trace elements of boron or phosphorous)

**Silicone** is a polymer of **silicon**, oxygen, carbon and hydrogen. Don't confuse the two.

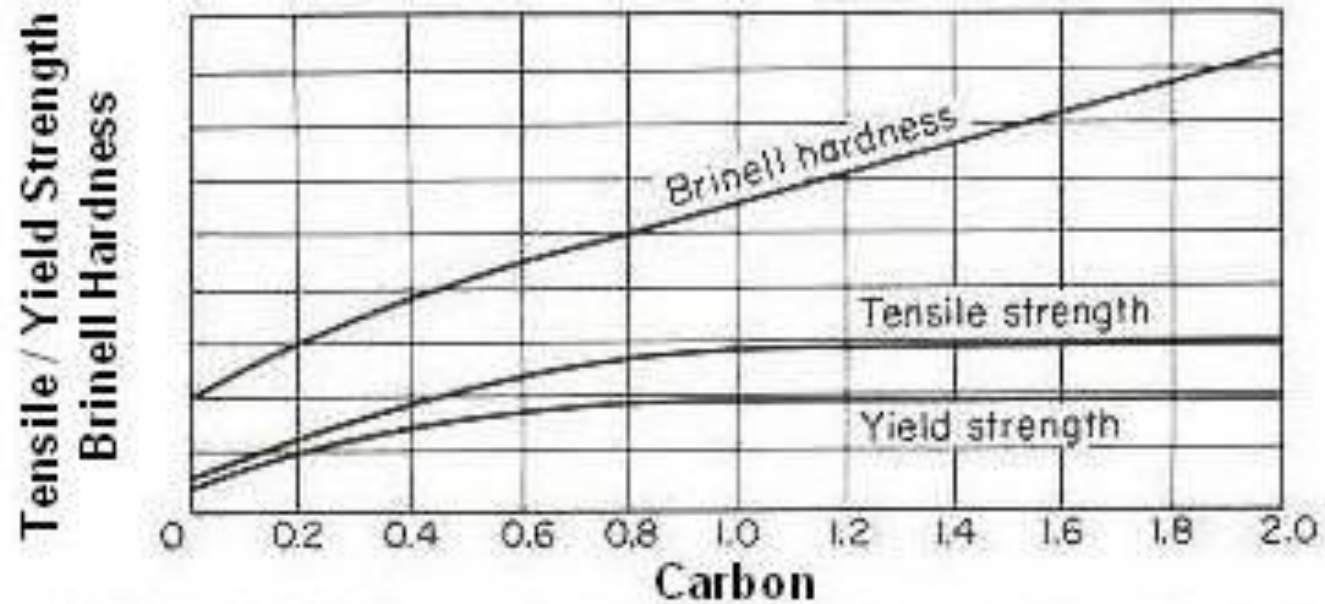
Silicon = cement, bricks, glass, computers, chips

Silicone = moulds, foam, coatings, cookware

# Carbon

- ▶ Element with the highest melting point.
- ▶ Carbon is the main element in polymers together with Hydrogen
- ▶ Carbon is unique in that it is known to form up to 10 million different compounds. Carbon is important to the existence of life

# Carbon



**Effect of Carbon on Mechanical Properties of Steel**

# Metals

- ▶ What is a metal?
- ▶ Example of a metal?
- ▶ What do we know about metals?

# Metals

|                                               |  |  |  |  |  |  |  |  |  |  |  |                                              |  |
|-----------------------------------------------|--|--|--|--|--|--|--|--|--|--|--|----------------------------------------------|--|
| <div>1</div> <div>H</div> <div>Hydrogen</div> |  |  |  |  |  |  |  |  |  |  |  | <div>2</div> <div>He</div> <div>Helium</div> |  |
|                                               |  |  |  |  |  |  |  |  |  |  |  |                                              |  |
|                                               |  |  |  |  |  |  |  |  |  |  |  |                                              |  |
|                                               |  |  |  |  |  |  |  |  |  |  |  |                                              |  |
|                                               |  |  |  |  |  |  |  |  |  |  |  |                                              |  |
|                                               |  |  |  |  |  |  |  |  |  |  |  |                                              |  |
|                                               |  |  |  |  |  |  |  |  |  |  |  |                                              |  |
|                                               |  |  |  |  |  |  |  |  |  |  |  |                                              |  |
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# Metal Properties Worksheet

| Property                  | Metals | Non-metals |
|---------------------------|--------|------------|
| Appearance                |        |            |
| State at room temperature |        |            |
| Density                   |        |            |
| Strength                  |        |            |
| Malleable or brittle      |        |            |
| Conduction of heat        |        |            |
| Conduction of electricity |        |            |
| Magnetic material         |        |            |
| Sound when hit            |        |            |

# Metals-Properties

All metals are:

- ▶ Solid
- ▶ Shiny
- ▶ Ductile
- ▶ Malleable
- ▶ Good conductors
- ▶ Lose electrons easily

Most metals:

- ▶ Are solid at room temperature
- ▶ Are hard and strong
- ▶ Have a high density
- ▶ Are sonorous
  
- ▶ Three metals are magnetic

# Metals-properties

- ▶ Crystal Structure
- ▶ Large number free electrons
- ▶ Metallic bond
- ▶ Good electrical conductivity
- ▶ Opaque
- ▶ Uniform atoms
- ▶ High tensile strength
- ▶ Low shear strength
- ▶ Good ductility
- ▶ Plastic flow
- ▶ Impact strength
- ▶ Relatively high weight
- ▶ Moderate hardness
- ▶ Non porous
- ▶ High density

# Metals-properties of ferrous metals

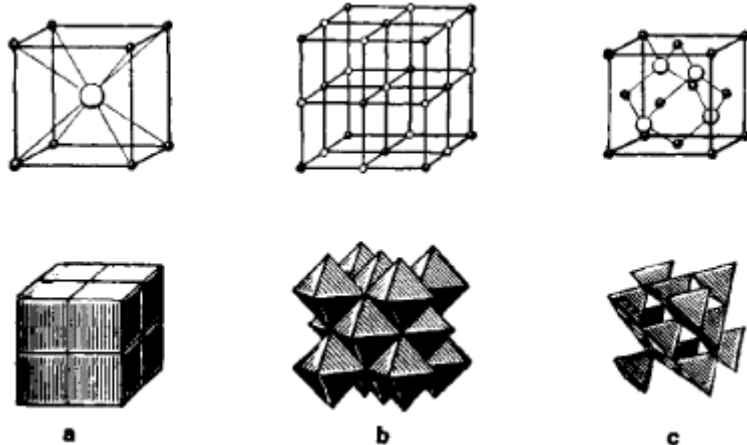
- ▶ Ferrous metals mild steel, carbon steel, stainless steel, cast iron, and wrought iron.
- ▶ used for their tensile strength and durability, especially mild steel which helps hold up the tallest skyscrapers and the longest bridges in the world.
- ▶ also find ferrous metals in housing construction, industrial containers, large-scale piping, automobiles, rails for railroad and transportation, most of tools and hardware you use around the house, and the knives you cook with at home.
- ▶ Due to the high amounts of carbon used when creating them, most ferrous metals and alloys are vulnerable to rust when exposed to the elements. While this isn't true of wrought iron, which is so iron pure that it resists oxidization, or stainless steel, which is protected thanks to its high chromium content, it's a good rule of thumb that if you see rust, it's a ferrous metal.
- ▶ Most ferrous metals also have magnetic properties, which makes them very useful in the creation of large motors and electrical appliances.
- ▶ Steady price - usually cheaper than non-ferrous metals.

# Metals-properties of non-ferrous metals

- ▶ Non-ferrous metals aluminum, brass, copper, nickel, tin, lead, and zinc, as well as precious metals like gold and silver. While non-ferrous metals can provide strength, they are primarily used where their differences from ferrous metals can provide an advantage.
- ▶ much more malleable than ferrous metals.
- ▶ much lighter, making them well-suited for use where strength is needed, but weight is a factor, such as in the aircraft or canning industries.
- ▶ Higher resistance to rust and corrosion, which is why you'll find these materials in use for gutters, water pipes, roofing, and road signs.
- ▶ non-magnetic, which makes them perfect for use in small electronics and as electrical wiring.
- ▶ Varying price - usually more expensive than ferrous metals

# Crystal Structures

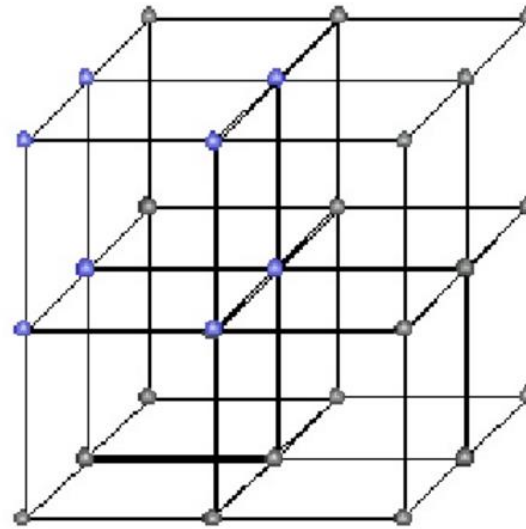
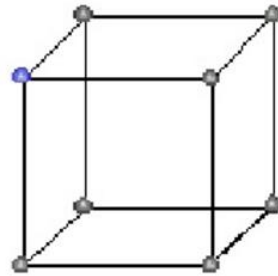
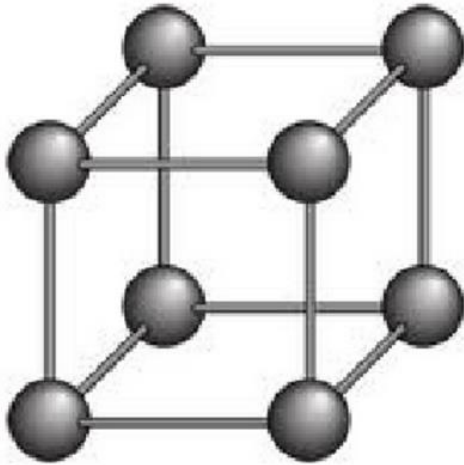
- ▶ Atoms form into a crystal lattice
- ▶ Structures that are not crystalline are called amorphous
- ▶ Metals are crystalline
- ▶ Polymers and ceramics can be crystalline and amorphous



## Co-ordination Number

Co-ordination number is the number of nearest equidistant neighboring atoms surrounding an atom under consideration

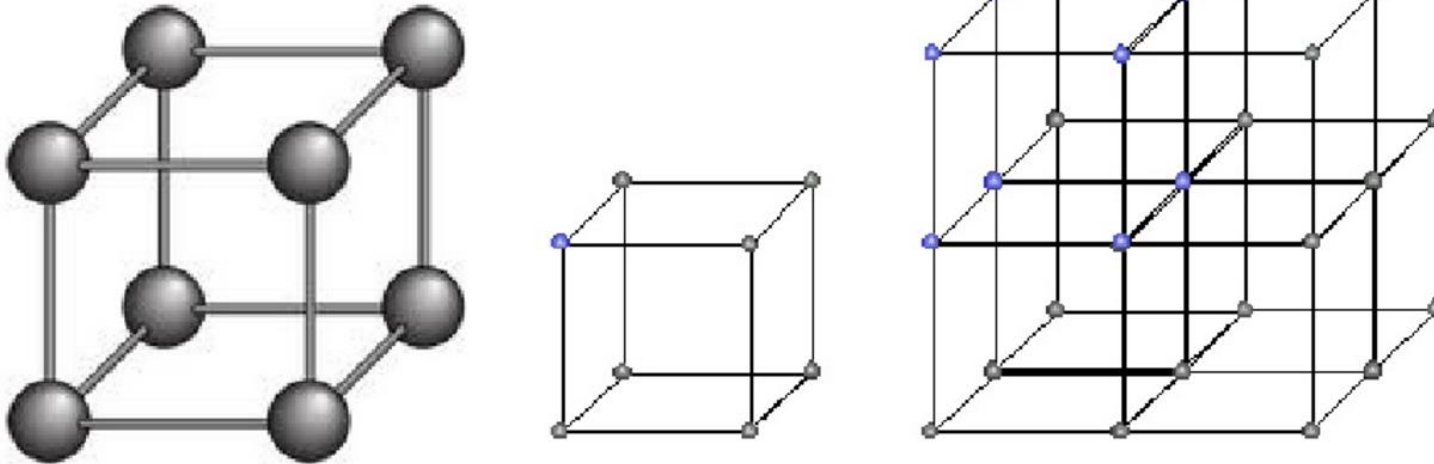
### 1. Simple Cubic Structure:



## Co-ordination Number

Co-ordination number is the number of nearest equidistant neighboring atoms surrounding an atom under consideration

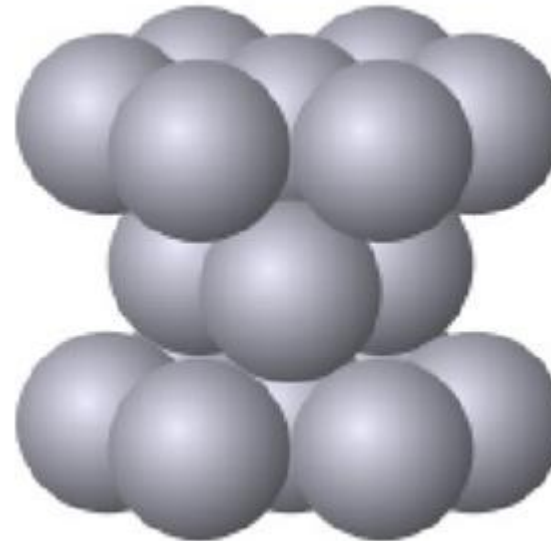
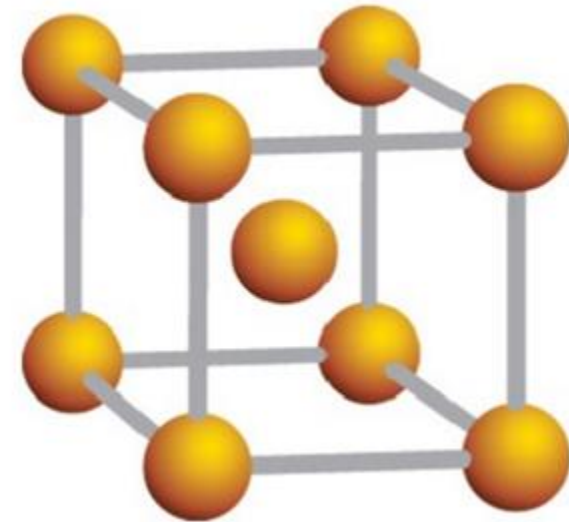
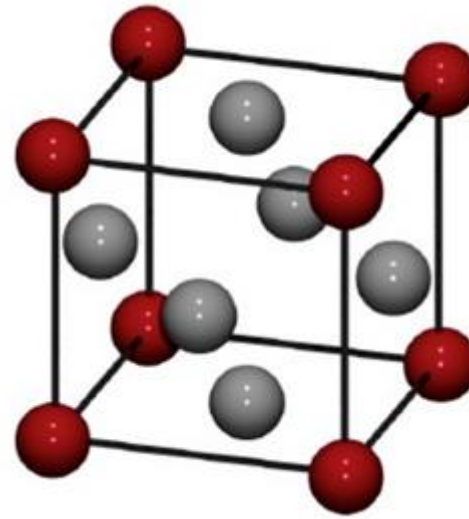
### 1. Simple Cubic Structure:



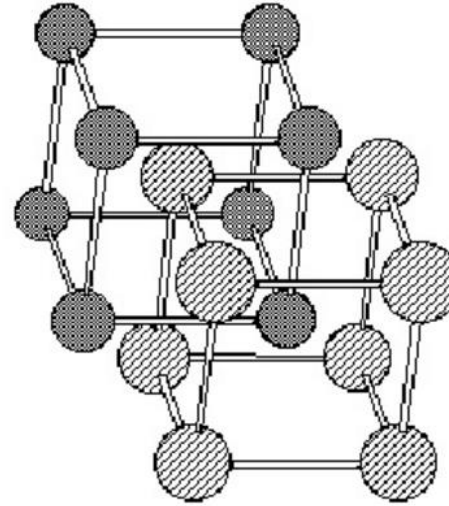
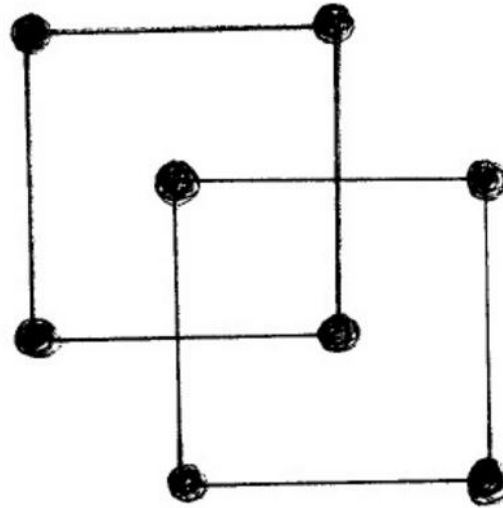
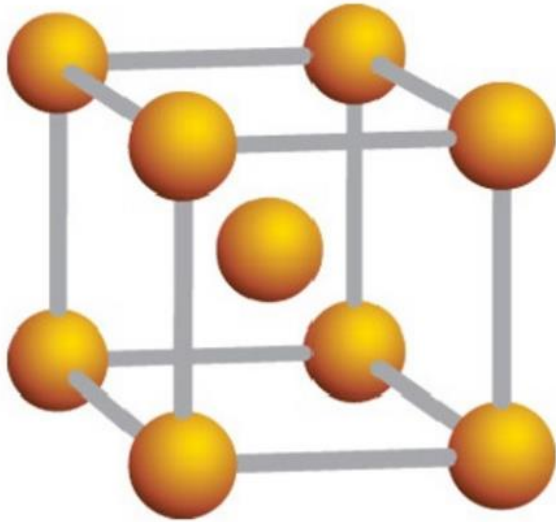
Simple cubic structure has a coordination number of **6**

# Metals - Structure

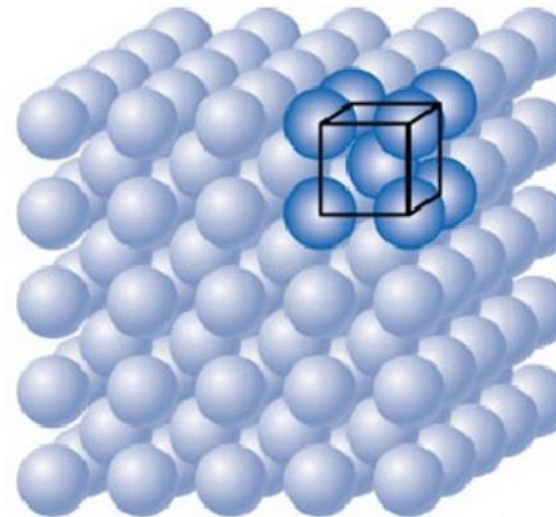
- ▶ The properties of some materials are related to their crystal structures.
- ▶ Face centred cubic structure FCC
- ▶ Body centred cubic structure BCC
- ▶ Hexagonal close-packed HCP



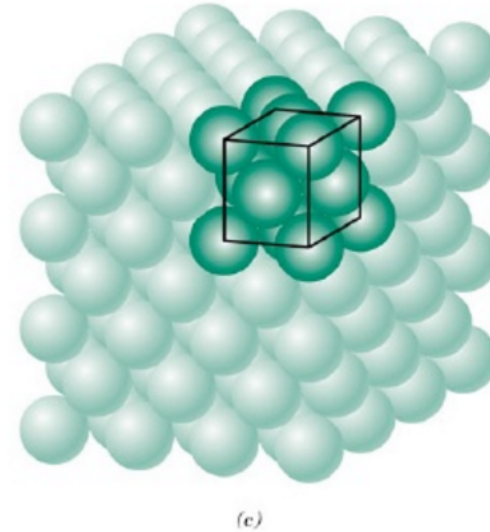
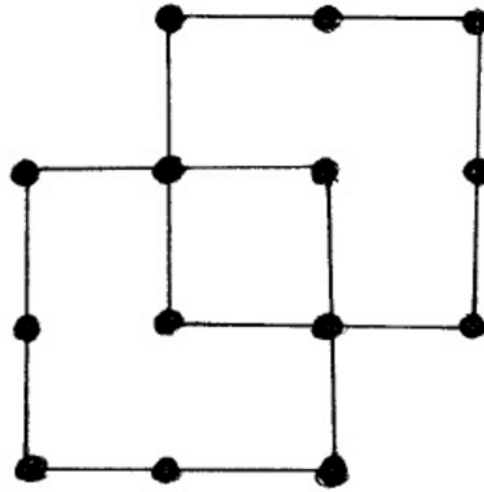
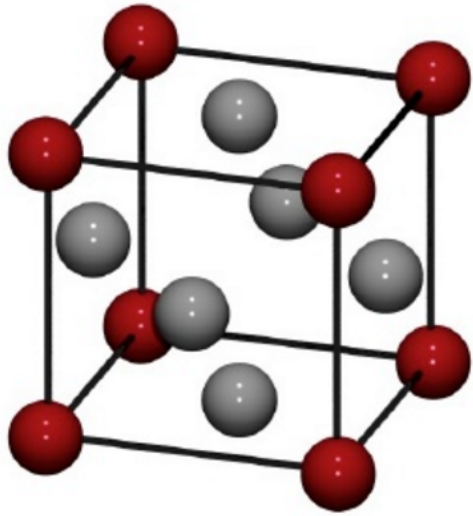
## 2. Body Centered Cubic Structure:



Body centered cubic structure has a coordination number of **8**

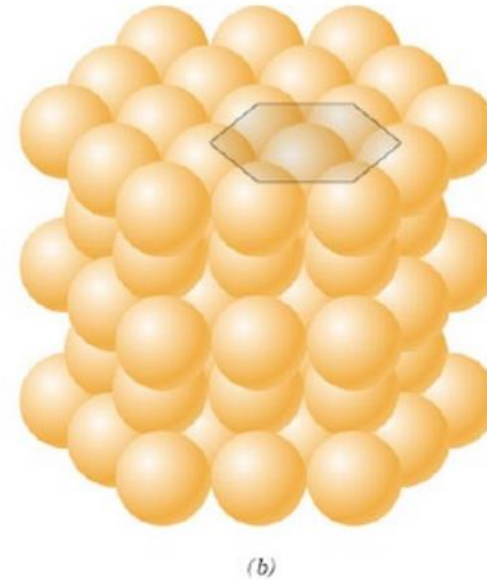
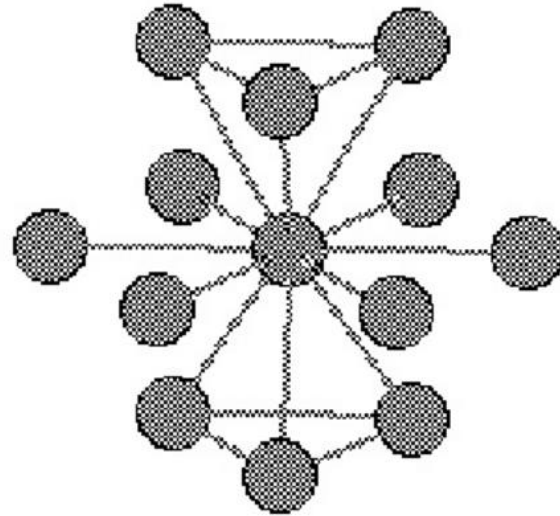
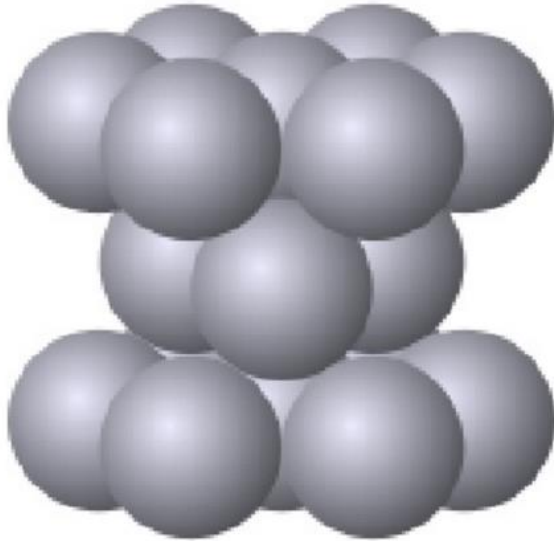


### 3. Face Centered Cubic Structure:



Face centered cubic structure has a coordination number of **12**

#### 4. Hexagonal Close Packed Structure:



Hexagonal close packed structure has a coordination number of **12**