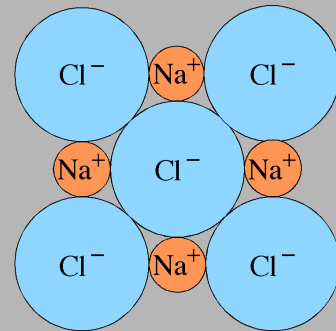
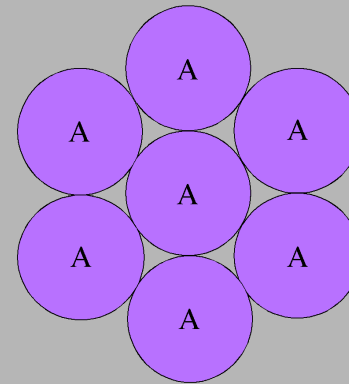


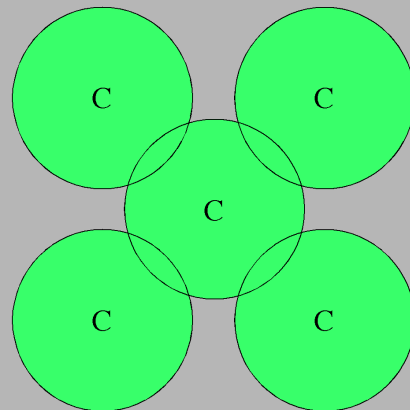
Today's lecture



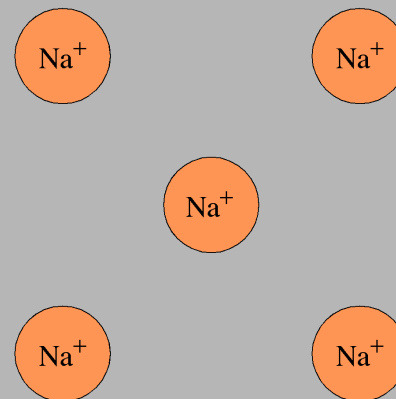
Natriumchlorid
(ionisch)



Kristallines Argon
(van der Waals)

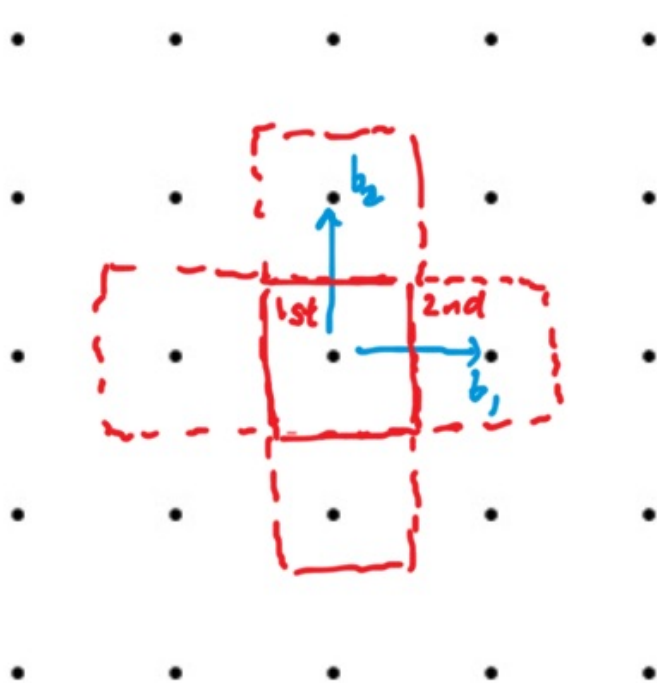


Diamant
(kovalent)

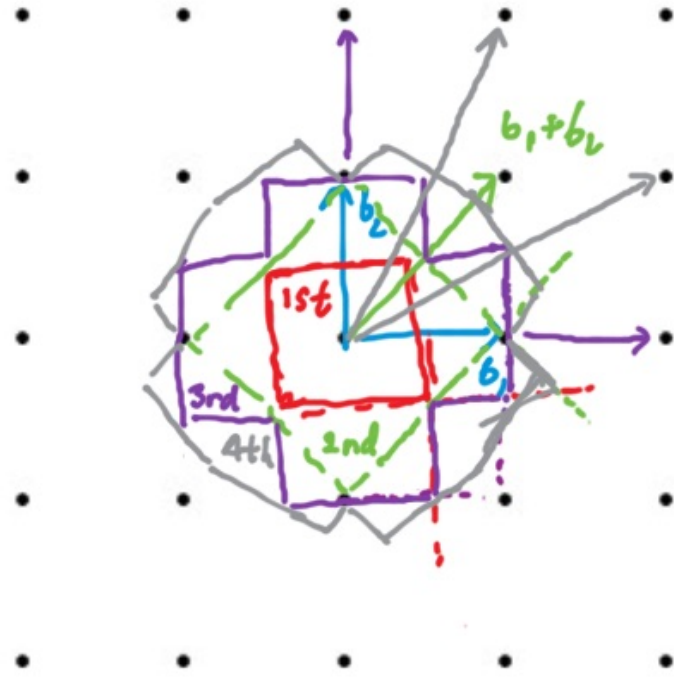


Natrium
(metallisch)

NOTE ON 2nd, 3rd... BRILLIOWN ZONES:



IN ELECTRONIC BAND
STRUCTURE LITERATURE
REFERENCE TO "2nd BRILLIOWN
ZONE" IS HAVING THE
MEANING AS SHOWN ABOVE.
THIS PROBABLY USEFUL
JARGON.



THIS IS THE STRICT
TEXT BOOK DEFINITION
OF HOW TO CONSTRUCT
HIGHER ORDER BRILLIOWN
ZONE.

THIS IS THE SCHEME TO
USE FOR EXERCISE 4 (sheet 2).

Periodic table

Periodic Table of the Elements

s
p
d
f

		Atomic Number										Atomic Mass																	
		Symbol										Name																	
		Electron Configuration																											
1 IA 1A	2 IIA 2A											13 IIIA 3A	14 IVA 4A	15 VA 5A	16 VIA 6A	17 VIIA 7A	18 VIIIA 8A												
1 H Hydrogen 1s ¹ 1.008												5 B Boron [He]2s ² 2p ¹ 10.811	6 C Carbon [He]2s ² 2p ² 12.011	7 N Nitrogen [He]2s ² 2p ³ 14.007	8 O Oxygen [He]2s ² 2p ⁴ 15.999	9 F Fluorine [He]2s ² 2p ⁵ 18.998	10 Ne Neon [He]2s ² 2p ⁶ 20.180												
3 Li Lithium [He]2s ¹ 6.941	4 Be Beryllium [He]2s ² 9.012											11 Na Sodium [Ne]3s ¹ 22.990	12 Mg Magnesium [Ne]3s ² 24.305											13 Al Aluminum [Ne]3s ² 3p ¹ 26.982	14 Si Silicon [Ne]3s ² 3p ² 28.086	15 P Phosphorus [Ne]3s ² 3p ³ 30.974	16 S Sulfur [Ne]3s ² 3p ⁴ 32.066	17 Cl Chlorine [Ne]3s ² 3p ⁵ 35.453	18 Ar Argon [Ne]3s ² 3p ⁶ 39.948
19 K Potassium [Ar]4s ¹ 39.098	20 Ca Calcium [Ar]4s ² 40.078	21 Sc Scandium [Ar]3d ¹ 4s ² 44.956	22 Ti Titanium [Ar]3d ² 4s ² 47.88	23 V Vanadium [Ar]3d ³ 4s ² 50.942	24 Cr Chromium [Ar]3d ⁵ 4s ¹ 51.996	25 Mn Manganese [Ar]3d ⁵ 4s ² 54.938	26 Fe Iron [Ar]3d ⁶ 4s ² 55.845	27 Co Cobalt [Ar]3d ⁷ 4s ² 58.933	28 Ni Nickel [Ar]3d ⁸ 4s ² 58.693	29 Cu Copper [Ar]3d ¹⁰ 4s ¹ 63.546	30 Zn Zinc [Ar]3d ¹⁰ 4s ² 65.38	31 Ga Gallium [Ar]3d ¹⁰ 4s ² 4p ¹ 69.723	32 Ge Germanium [Ar]3d ¹⁰ 4s ² 4p ² 72.631	33 As Arsenic [Ar]3d ¹⁰ 4s ² 4p ³ 74.922	34 Se Selenium [Ar]3d ¹⁰ 4s ² 4p ⁴ 78.971	35 Br Bromine [Ar]3d ¹⁰ 4s ² 4p ⁵ 79.904	36 Kr Krypton [Ar]3d ¹⁰ 4s ² 4p ⁶ 84.798												
37 Rb Rubidium [Kr]5s ¹ 84.468	38 Sr Strontium [Kr]5s ² 87.62	39 Y Yttrium [Kr]4d ¹ 5s ² 88.906	40 Zr Zirconium [Kr]4d ² 5s ² 91.224	41 Nb Niobium [Kr]4d ⁴ 5s ¹ 92.906	42 Mo Molybdenum [Kr]4d ⁵ 5s ¹ 95.95	43 Tc Technetium [Kr]4d ⁵ 5s ² 98.907	44 Ru Ruthenium [Kr]4d ⁷ 5s ¹ 101.07	45 Rh Rhodium [Kr]4d ⁸ 5s ¹ 102.906	46 Pd Palladium [Kr]4d ¹⁰ 106.42	47 Ag Silver [Kr]4d ¹⁰ 5s ¹ 107.868	48 Cd Cadmium [Kr]4d ¹⁰ 5s ² 112.414	49 In Indium [Kr]4d ¹⁰ 5s ² 5p ¹ 114.818	50 Sn Tin [Kr]4d ¹⁰ 5s ² 5p ² 118.711	51 Sb Antimony [Kr]4d ¹⁰ 5s ² 5p ³ 121.760	52 Te Tellurium [Kr]4d ¹⁰ 5s ² 5p ⁴ 127.6	53 I Iodine [Kr]4d ¹⁰ 5s ² 5p ⁵ 126.904	54 Xe Xenon [Kr]4d ¹⁰ 5s ² 5p ⁶ 131.29												
55 Cs Cesium [Xe]6s ¹ 132.905	56 Ba Barium [Xe]6s ² 137.328	57-71 Lanthanide Series	72 Hf Hafnium [Xe]4f ¹⁴ 5d ² 6s ² 178.49	73 Ta Tantalum [Xe]4f ¹⁴ 5d ³ 6s ² 180.948	74 W Tungsten [Xe]4f ¹⁴ 5d ⁴ 6s ² 183.84	75 Re Rhenium [Xe]4f ¹⁴ 5d ⁵ 6s ² 186.207	76 Os Osmium [Xe]4f ¹⁴ 5d ⁶ 6s ² 190.23	77 Ir Iridium [Xe]4f ¹⁴ 5d ⁷ 6s ² 192.217	78 Pt Platinum [Xe]4f ¹⁴ 5d ⁹ 6s ¹ 195.085	79 Au Gold [Xe]4f ¹⁴ 5d ¹⁰ 6s ¹ 196.967	80 Hg Mercury [Xe]4f ¹⁴ 5d ¹⁰ 6s ² 200.592	81 Tl Thallium [Xe]4f ¹⁴ 5d ¹⁰ 6s ² 6p ¹ 204.383	82 Pb Lead [Xe]4f ¹⁴ 5d ¹⁰ 6s ² 6p ² 207.2	83 Bi Bismuth [Xe]4f ¹⁴ 5d ¹⁰ 6s ² 6p ³ 208.980	84 Po Polonium [Xe]4f ¹⁴ 5d ¹⁰ 6s ² 6p ⁴ [209]	85 At Astatine [Xe]4f ¹⁴ 5d ¹⁰ 6s ² 6p ⁵ [209]	86 Rn Radon [Xe]4f ¹⁴ 5d ¹⁰ 6s ² 6p ⁶ 222.018												
87 Fr Francium [Rn]7s ¹ 223.020	88 Ra Radium [Rn]7s ² 226.025	89-103 Actinide Series	104 Rf Rutherfordium [Rn]5f ¹⁴ 6d ² 7s ² [261]	105 Db Dubnium [Rn]5f ¹⁴ 6d ³ 7s ² [262]	106 Sg Seaborgium [Rn]5f ¹⁴ 6d ⁴ 7s ² [266]	107 Bh Bohrium [Rn]5f ¹⁴ 6d ⁵ 7s ² [264]	108 Hs Hassium [Rn]5f ¹⁴ 6d ⁶ 7s ² [269]	109 Mt Meitnerium [Rn]5f ¹⁴ 6d ⁷ 7s ² [268]	110 Ds Darmstadtium [Rn]5f ¹⁴ 6d ⁸ 7s ² [271]	111 Rg Roentgenium [Rn]5f ¹⁴ 6d ⁹ 7s ² [272]	112 Cn Copernicium [Rn]5f ¹⁴ 6d ¹⁰ 7s ² [277]	113 Uut Ununtrium [Rn]5f ¹⁴ 6d ¹⁰ 7s ² 7p ¹ [289]	114 Fl Flerovium [Rn]5f ¹⁴ 6d ¹⁰ 7s ² 7p ² [289]	115 Uup Ununpentium [Rn]5f ¹⁴ 6d ¹⁰ 7s ² 7p ³ [289]	116 Lv Livermorium [Rn]5f ¹⁴ 6d ¹⁰ 7s ² 7p ⁴ [289]	117 Uus Ununseptium [Rn]5f ¹⁴ 6d ¹⁰ 7s ² 7p ⁵ [289]	118 Uuo Ununoctium [Rn]5f ¹⁴ 6d ¹⁰ 7s ² 7p ⁶ [289]												
		57 La Lanthanum [Xe]5d ¹ 6s ² 138.905	58 Ce Cerium [Xe]4f ¹ 5d ¹ 6s ² 140.116	59 Pr Praseodymium [Xe]4f ³ 6s ² 140.908	60 Nd Neodymium [Xe]4f ⁴ 6s ² 144.243	61 Pm Promethium [Xe]4f ⁵ 6s ² 144.913	62 Sm Samarium [Xe]4f ⁶ 6s ² 150.36	63 Eu Europium [Xe]4f ⁷ 6s ² 151.964	64 Gd Gadolinium [Xe]4f ⁷ 5d ¹ 6s ² 157.25	65 Tb Terbium [Xe]4f ⁹ 6s ² 158.925	66 Dy Dysprosium [Xe]4f ¹⁰ 6s ² 162.500	67 Ho Holmium [Xe]4f ¹¹ 6s ² 164.930	68 Er Erbium [Xe]4f ¹² 6s ² 167.259	69 Tm Thulium [Xe]4f ¹³ 6s ² 168.934	70 Yb Ytterbium [Xe]4f ¹⁴ 6s ² 173.055	71 Lu Lutetium [Xe]4f ¹⁴ 5d ¹ 6s ² 174.967													
		89 Ac Actinium [Rn]6d ¹ 7s ² 227.028	90 Th Thorium [Rn]6d ² 7s ² 232.038	91 Pa Protactinium [Rn]5f ² 6d ¹ 7s ² 231.036	92 U Uranium [Rn]5f ³ 6d ¹ 7s ² 238.029	93 Np Neptunium [Rn]5f ⁴ 6d ¹ 7s ² 237.048	94 Pu Plutonium [Rn]5f ⁶ 7s ² 244.064	95 Am Americium [Rn]5f ⁷ 7s ² 243.061	96 Cm Curium [Rn]5f ⁸ 6d ¹ 7s ² 247.070	97 Bk Berkelium [Rn]5f ⁹ 7s ² 247.070	98 Cf Californium [Rn]5f ¹⁰ 7s ² 251.080	99 Es Einsteinium [Rn]5f ¹¹ 7s ² [254]	100 Fm Fermium [Rn]5f ¹² 7s ² 257.085	101 Md Mendelevium [Rn]5f ¹³ 7s ² 258.1	102 No Nobelium [Rn]5f ¹⁴ 7s ² 259.101	103 Lr Lawrencium [Rn]5f ¹⁴ 6d ¹ 7s ² [262]													

COMMON CRYSTAL STRUCTURES

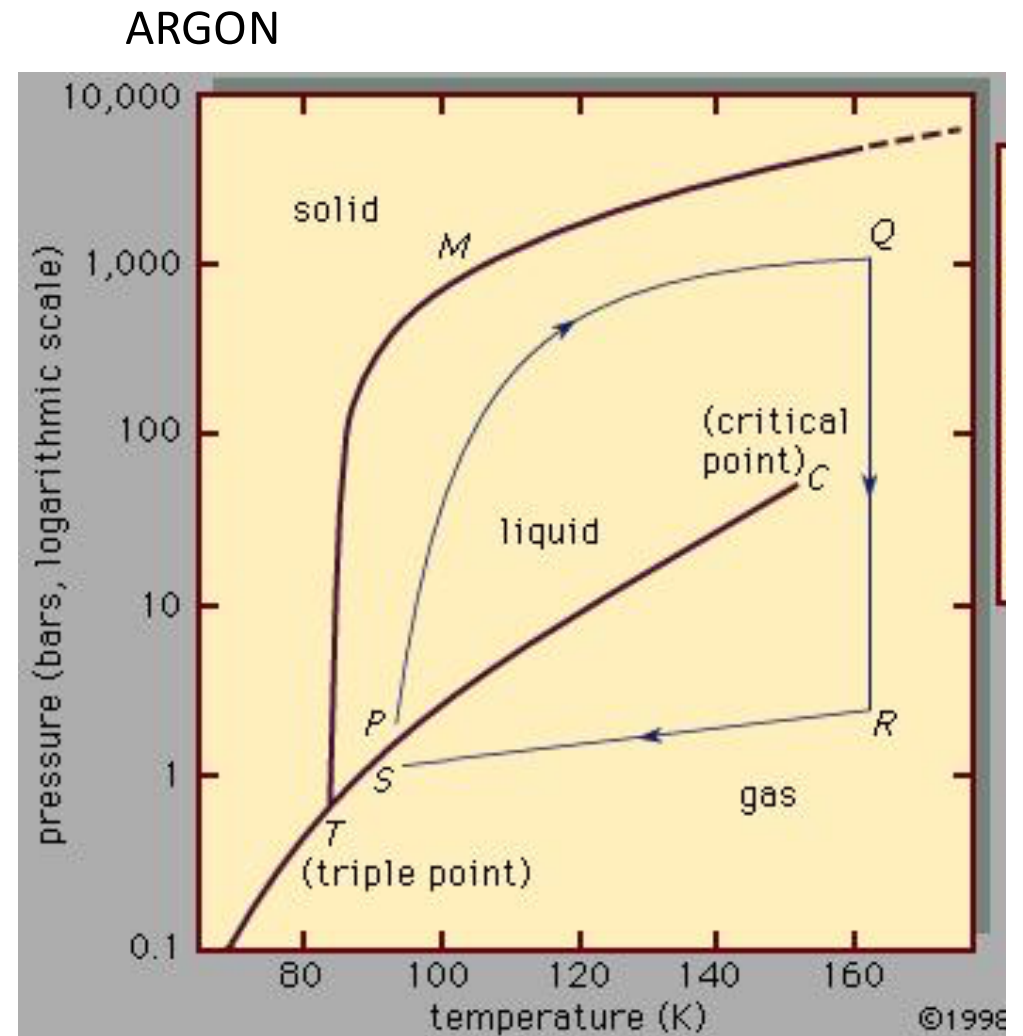
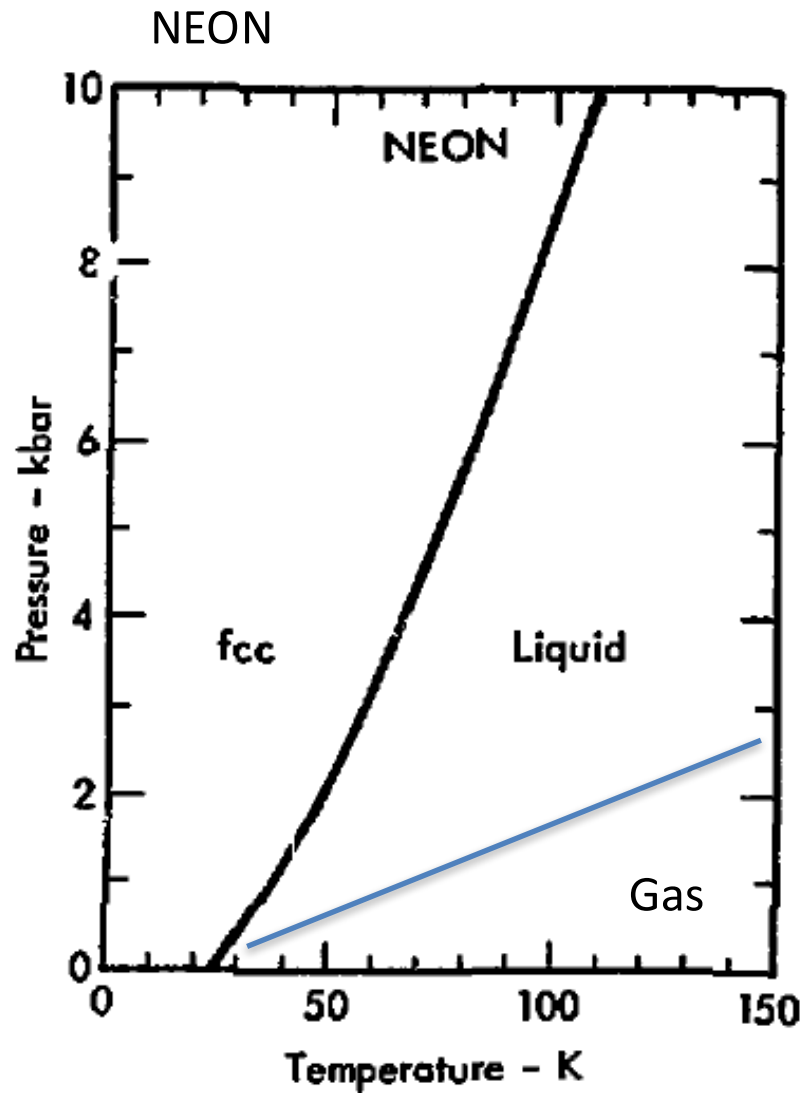
BCC - Structure

Name	Sym	#
<u>Barium</u>	<u>Ba</u>	<u>56</u>
<u>Cesium</u>	<u>Cs</u>	<u>55</u>
<u>Chromium</u>	<u>Cr</u>	<u>24</u>
<u>Europium</u>	<u>Eu</u>	<u>63</u>
<u>Francium</u>	<u>Fr</u>	<u>87</u>
<u>Iron</u>	<u>Fe</u>	<u>26</u>
<u>Lithium</u>	<u>Li</u>	<u>3</u>
<u>Manganese</u>	<u>Mn</u>	<u>25</u>
<u>Molybdenum</u>	<u>Mo</u>	<u>42</u>
<u>Niobium</u>	<u>Nb</u>	<u>41</u>
<u>Potassium</u>	<u>K</u>	<u>19</u>
<u>Radium</u>	<u>Ra</u>	<u>88</u>
<u>Rubidium</u>	<u>Rb</u>	<u>37</u>
<u>Sodium</u>	<u>Na</u>	<u>11</u>
<u>Tantalum</u>	<u>Ta</u>	<u>73</u>
<u>Tungsten</u>	<u>W</u>	<u>74</u>
<u>Vanadium</u>	<u>V</u>	<u>23</u>

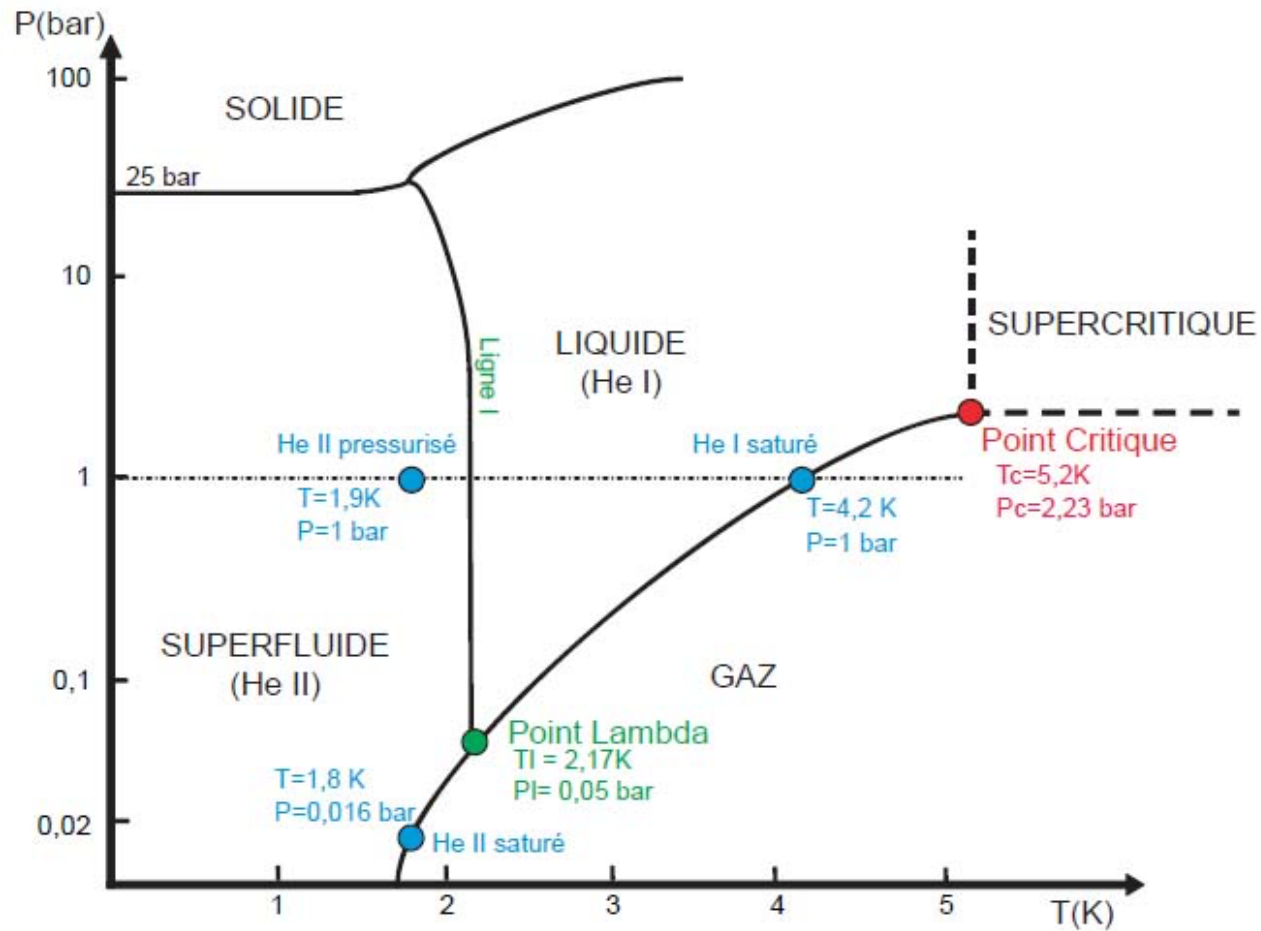
FCC - Structure

Name	Sym	#
<u>Neon Ne 10</u>		
<u>Aluminum Al 13</u>		
<u>Argon Ar 18</u>		
<u>Calcium Ca 20</u>		
<u>Cerium Ce 58</u>		
<u>Copper Cu 29</u>		
<u>Einsteinium Es 99</u>		
<u>Germanium Ge 32</u>		
<u>Gold Au 79</u>		
<u>Iridium Ir 77</u>		
<u>Krypton Kr 36</u>		
<u>Lead Pb 82</u>		
<u>Nickel Ni 28</u>		
<u>Xenon Xe 54</u>		
<u>Platinum Pt 78</u>		
<u>Radon Rn 86</u>		
<u>Rhodium Rh 45</u>		

Inert Gasses: Phase diagram

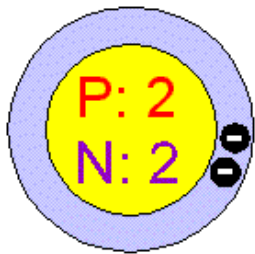


Phase diagram of helium

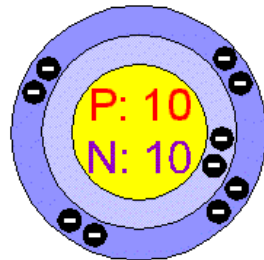


Inert Gasses

Helium

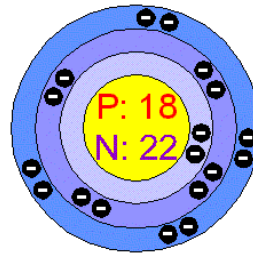


Neon



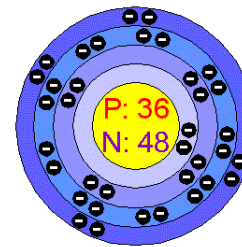
Melting point = 24 K

Argon



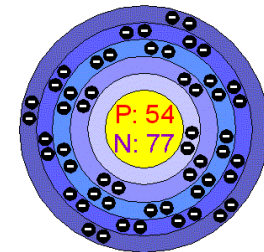
84 K

Krypton



117 K

Xenon

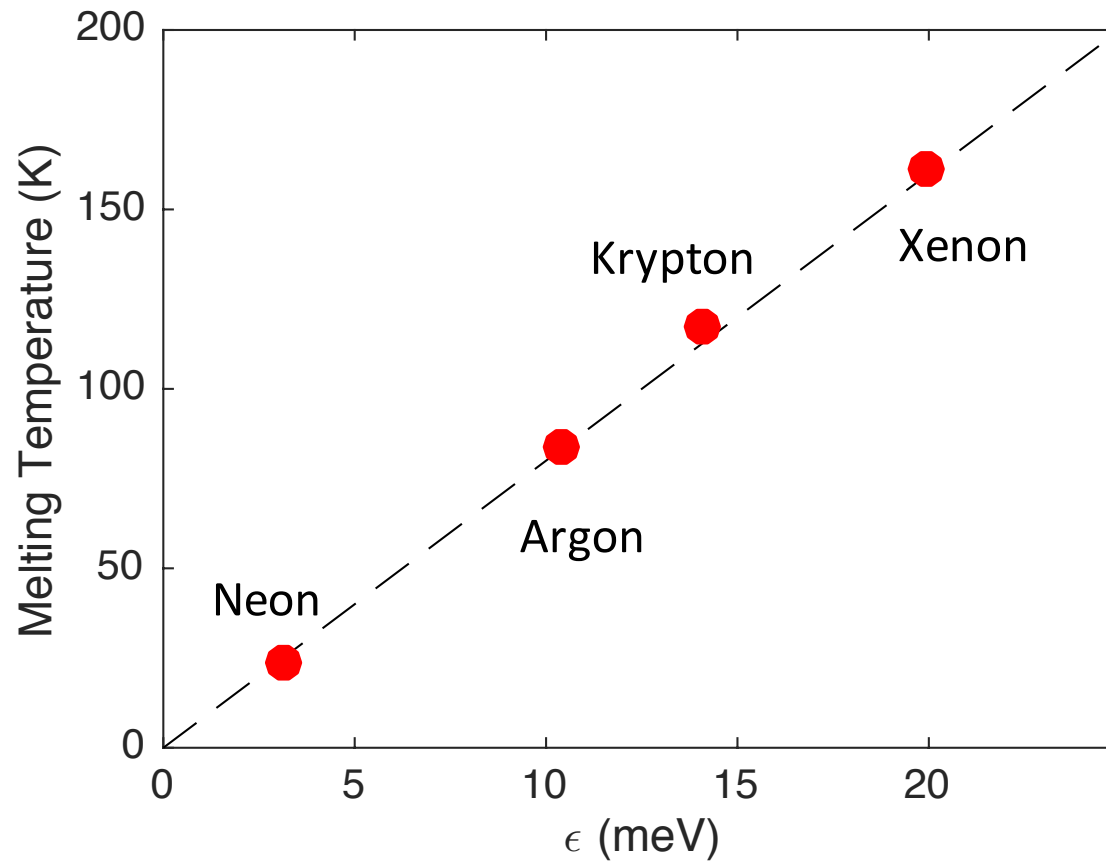


161 K

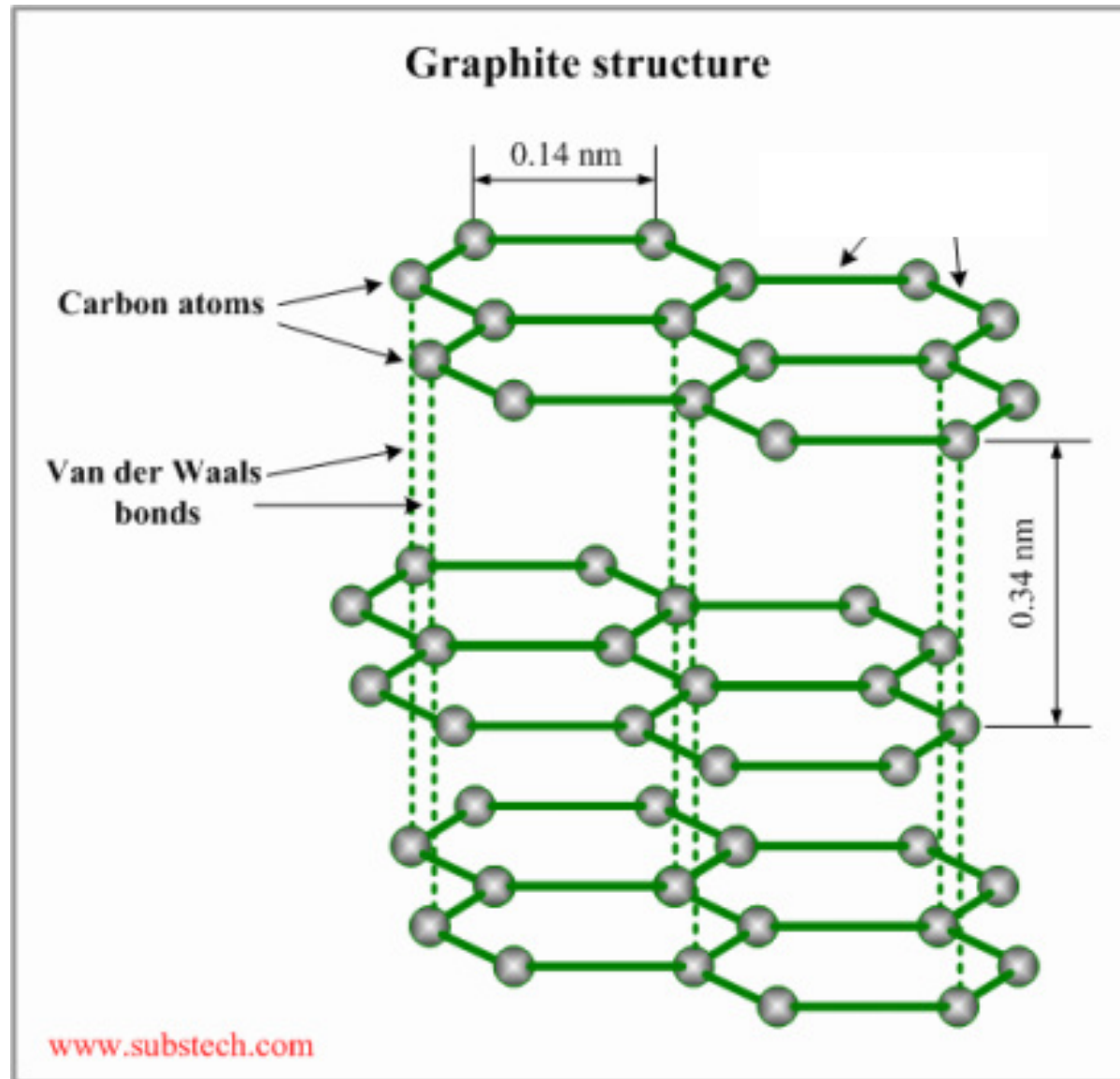
Questions:

- (1) Why are gasses solidifying in FCC rather than BCC?
- (2) What are the “glue” that binds these atoms together in the solid form?
- (3) Why are the melting point rather low?
- (4) Why are the inert gasses having different melting points?

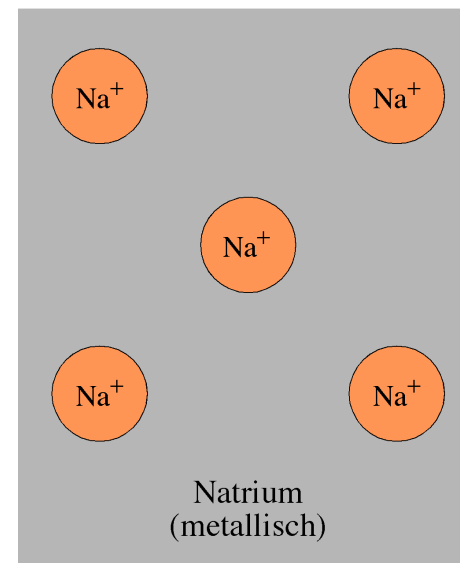
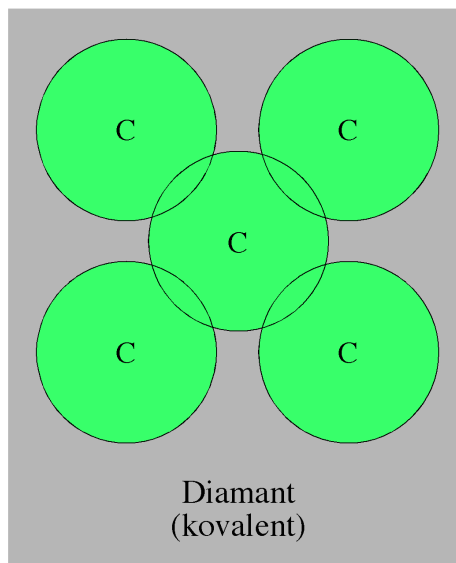
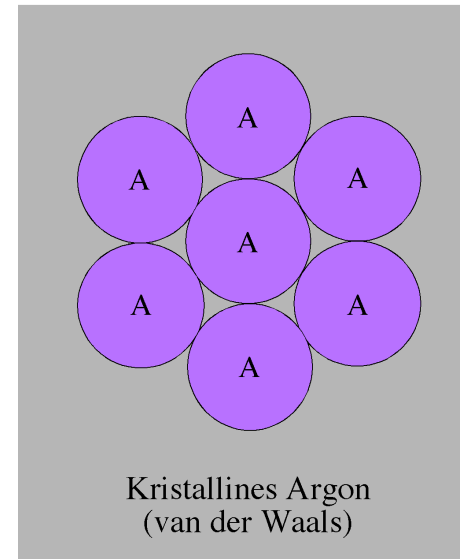
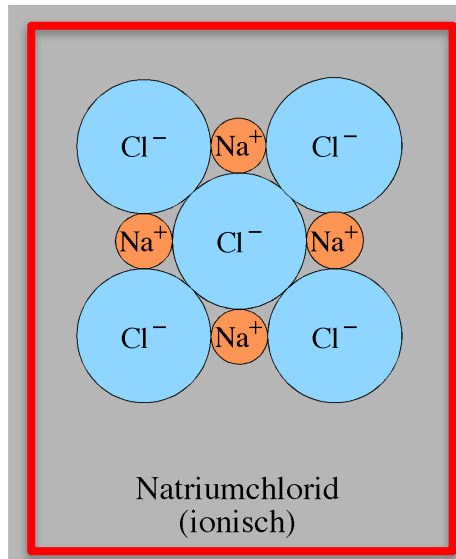
Why the melting temperature varies?



Van der Waals bonds



Today's lecture



Periodic table

Periodic Table of the Elements

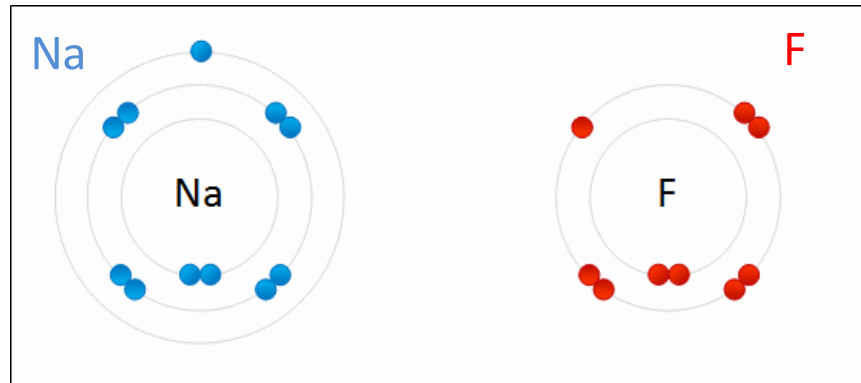
s
p
d
f

Atomic Number	Atomic Mass
Symbol	
Name	
Electron Configuration	

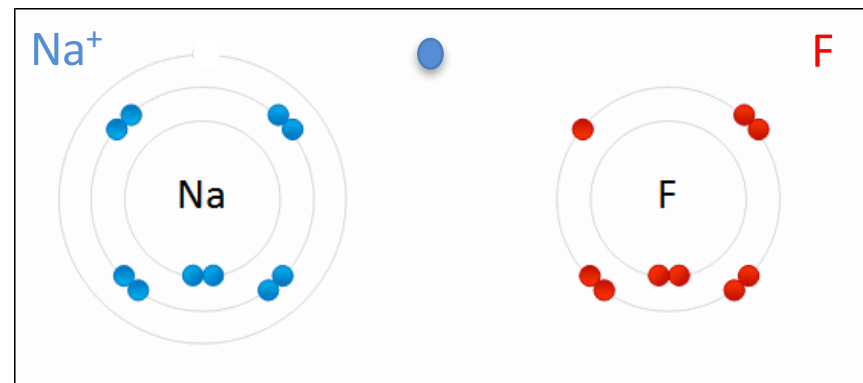
1 IA 1A		2 IIA 2A												13 IIIA 3A	14 IVA 4A	15 VA 5A	16 VIA 6A	17 VIIA 7A	18 VIIIA 8A				
1 H Hydrogen 1s ¹		3 Li Lithium [He]2s ¹	4 Be Beryllium [He]2s ²															5 B Boron [He]2s ² 2p ¹	6 C Carbon [He]2s ² 2p ²	7 N Nitrogen [He]2s ² 2p ³	8 O Oxygen [He]2s ² 2p ⁴	9 F Fluorine [He]2s ² 2p ⁵	10 Ne Neon [He]2s ² 2p ⁶
11 Na Sodium [Ne]3s ¹	12 Mg Magnesium [Ne]3s ²			3 III B 3B	4 IV B 4B	5 V B 5B	6 VI B 6B	7 VII B 7B	8 VIII 8	9 VIII 8	10 VIII 8	11 IB 1B	12 IIB 2B	13 Al Aluminum [Ne]3s ² 3p ¹	14 Si Silicon [Ne]3s ² 3p ²	15 P Phosphorus [Ne]3s ² 3p ³	16 S Sulfur [Ne]3s ² 3p ⁴	17 Cl Chlorine [Ne]3s ² 3p ⁵	18 Ar Argon [Ne]3s ² 3p ⁶				
19 K Potassium [Ar]4s ¹	20 Ca Calcium [Ar]4s ²	21 Sc Scandium [Ar]3d ¹ 4s ²	22 Ti Titanium [Ar]3d ² 4s ²	23 V Vanadium [Ar]3d ³ 4s ²	24 Cr Chromium [Ar]3d ⁵ 4s ¹	25 Mn Manganese [Ar]3d ⁵ 4s ²	26 Fe Iron [Ar]3d ⁶ 4s ²	27 Co Cobalt [Ar]3d ⁷ 4s ²	28 Ni Nickel [Ar]3d ⁸ 4s ²	29 Cu Copper [Ar]3d ¹⁰ 4s ¹	30 Zn Zinc [Ar]3d ¹⁰ 4s ²	31 Ga Gallium [Ar]3d ¹⁰ 4s ² 4p ¹	32 Ge Germanium [Ar]3d ¹⁰ 4s ² 4p ²	33 As Arsenic [Ar]3d ¹⁰ 4s ² 4p ³	34 Se Selenium [Ar]3d ¹⁰ 4s ² 4p ⁴	35 Br Bromine [Ar]3d ¹⁰ 4s ² 4p ⁵	36 Kr Krypton [Ar]3d ¹⁰ 4s ² 4p ⁶						
37 Rb Rubidium [Kr]5s ¹	38 Sr Strontium [Kr]5s ²	39 Y Yttrium [Kr]4d ¹ 5s ²	40 Zr Zirconium [Kr]4d ² 5s ²	41 Nb Niobium [Kr]4d ⁴ 5s ¹	42 Mo Molybdenum [Kr]4d ⁵ 5s ¹	43 Tc Technetium [Kr]4d ⁵ 5s ²	44 Ru Ruthenium [Kr]4d ⁷ 5s ¹	45 Rh Rhodium [Kr]4d ⁸ 5s ¹	46 Pd Palladium [Kr]4d ¹⁰	47 Ag Silver [Kr]4d ¹⁰ 5s ¹	48 Cd Cadmium [Kr]4d ¹⁰ 5s ²	49 In Indium [Kr]4d ¹⁰ 5s ² 5p ¹	50 Sn Tin [Kr]4d ¹⁰ 5s ² 5p ²	51 Sb Antimony [Kr]4d ¹⁰ 5s ² 5p ³	52 Te Tellurium [Kr]4d ¹⁰ 5s ² 5p ⁴	53 I Iodine [Kr]4d ¹⁰ 5s ² 5p ⁵	54 Xe Xenon [Kr]4d ¹⁰ 5s ² 5p ⁶						
55 Cs Cesium [Xe]6s ¹	56 Ba Barium [Xe]6s ²	57-71 Lanthanide Series	72 Hf Hafnium [Xe]4f ¹⁴ 5d ² 6s ²	73 Ta Tantalum [Xe]4f ¹⁴ 5d ³ 6s ²	74 W Tungsten [Xe]4f ¹⁴ 5d ⁴ 6s ²	75 Re Rhenium [Xe]4f ¹⁴ 5d ⁵ 6s ²	76 Os Osmium [Xe]4f ¹⁴ 5d ⁶ 6s ²	77 Ir Iridium [Xe]4f ¹⁴ 5d ⁷ 6s ²	78 Pt Platinum [Xe]4f ¹⁴ 5d ⁹ 6s ¹	79 Au Gold [Xe]4f ¹⁴ 5d ¹⁰ 6s ¹	80 Hg Mercury [Xe]4f ¹⁴ 5d ¹⁰ 6s ²	81 Tl Thallium [Xe]4f ¹⁴ 5d ¹⁰ 6s ² 6p ¹	82 Pb Lead [Xe]4f ¹⁴ 5d ¹⁰ 6s ² 6p ²	83 Bi Bismuth [Xe]4f ¹⁴ 5d ¹⁰ 6s ² 6p ³	84 Po Polonium [Xe]4f ¹⁴ 5d ¹⁰ 6s ² 6p ⁴	85 At Astatine [Xe]4f ¹⁴ 5d ¹⁰ 6s ² 6p ⁵	86 Rn Radon [Xe]4f ¹⁴ 5d ¹⁰ 6s ² 6p ⁶						
87 Fr Francium [Rn]7s ¹	88 Ra Radium [Rn]7s ²	89-103 Actinide Series	104 Rf Rutherfordium [Rn]5f ¹⁴ 6d ² 7s ²	105 Db Dubnium [Rn]5f ¹⁴ 6d ³ 7s ²	106 Sg Seaborgium [Rn]5f ¹⁴ 6d ⁴ 7s ²	107 Bh Bohrium [Rn]5f ¹⁴ 6d ⁵ 7s ²	108 Hs Hassium [Rn]5f ¹⁴ 6d ⁶ 7s ²	109 Mt Meitnerium [Rn]5f ¹⁴ 6d ⁷ 7s ²	110 Ds Darmstadtium [Rn]5f ¹⁴ 6d ⁸ 7s ²	111 Rg Roentgenium [Rn]5f ¹⁴ 6d ⁹ 7s ²	112 Cn Copernicium [Rn]5f ¹⁴ 6d ¹⁰ 7s ²	113 Uut Ununtrium [Rn]5f ¹⁴ 6d ¹⁰ 7s ² 7p ¹	114 Fl Flerovium [Rn]5f ¹⁴ 6d ¹⁰ 7s ² 7p ²	115 Uup Ununpentium [Rn]5f ¹⁴ 6d ¹⁰ 7s ² 7p ³	116 Lv Livermorium [Rn]5f ¹⁴ 6d ¹⁰ 7s ² 7p ⁴	117 Uus Ununseptium [Rn]5f ¹⁴ 6d ¹⁰ 7s ² 7p ⁵	118 Uuo Ununoctium [Rn]5f ¹⁴ 6d ¹⁰ 7s ² 7p ⁶						

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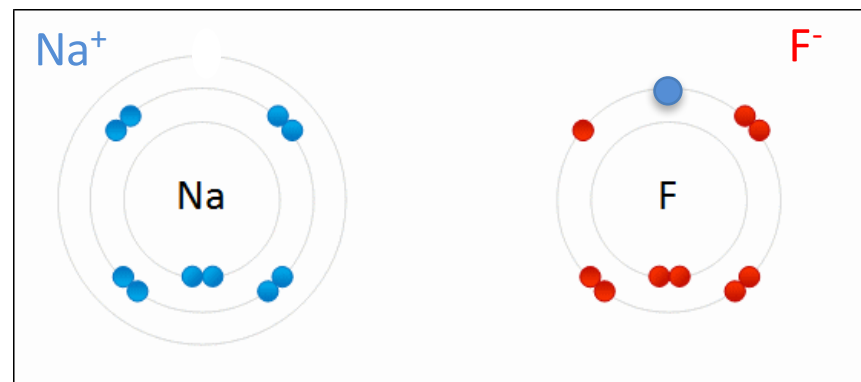
Ionic crystals – Example



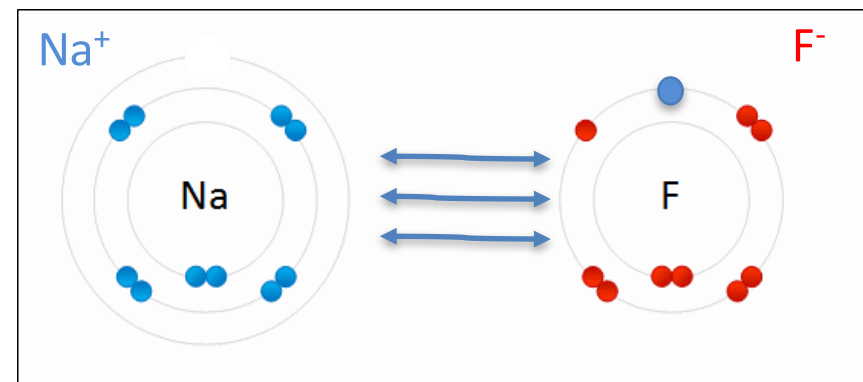
Ionization Energy = - 5.14 eV



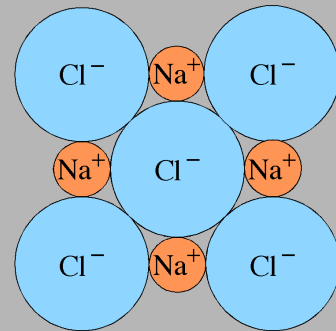
Electron affinity Energy = 3.4 eV



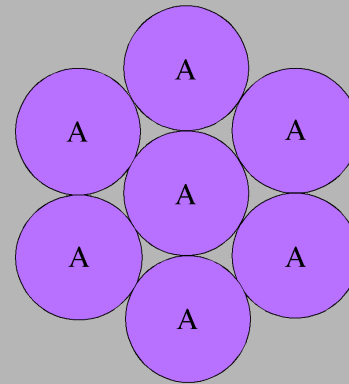
Cohesive Energy = 7.9 eV



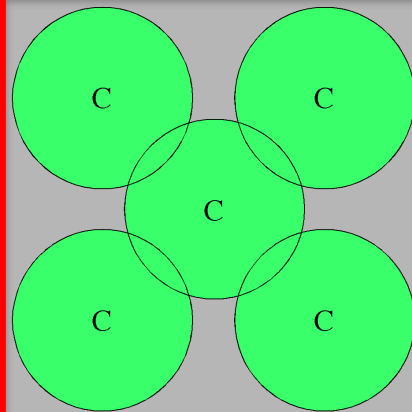
Today's lecture



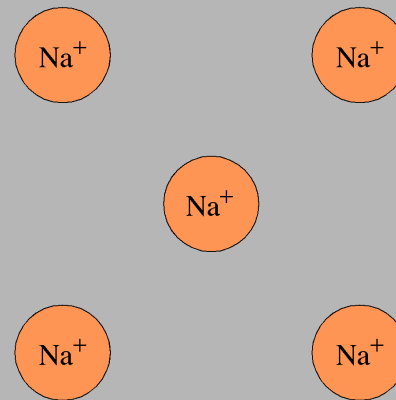
Natriumchlorid
(ionisch)



Kristallines Argon
(van der Waals)

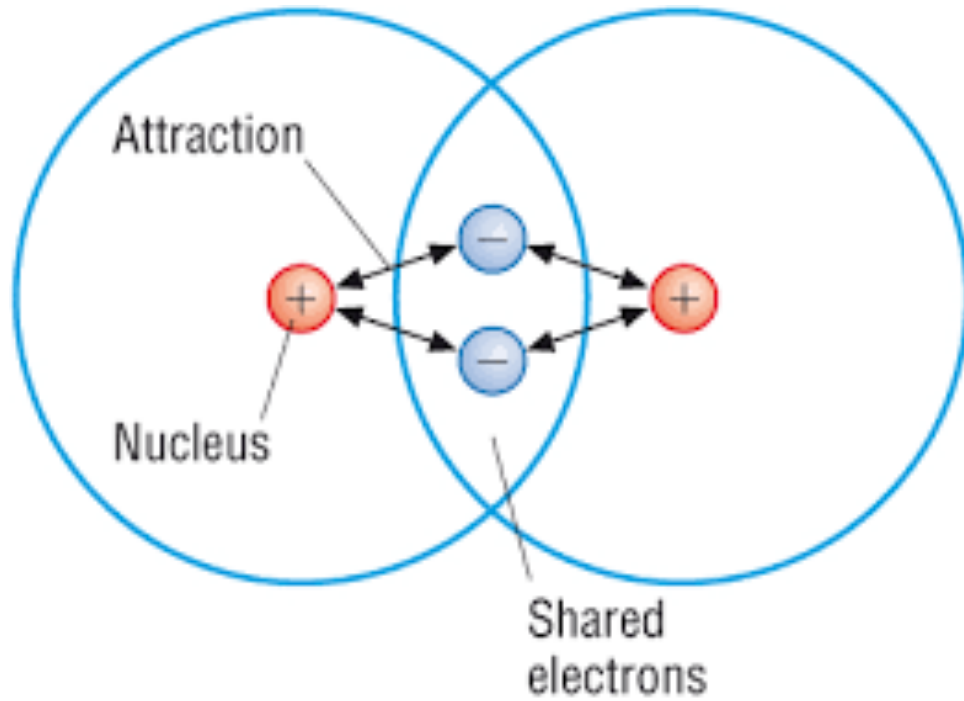


Diamant
(kovalent)

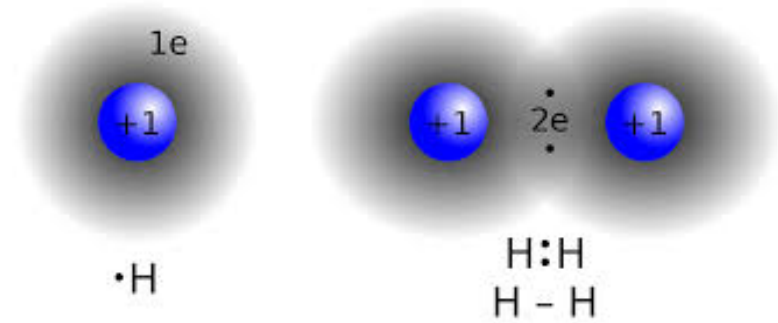


Natrium
(metallisch)

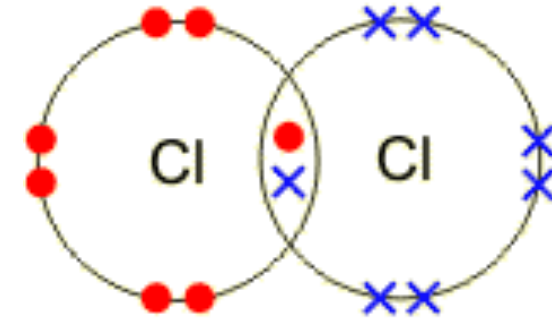
Covalent Crystals



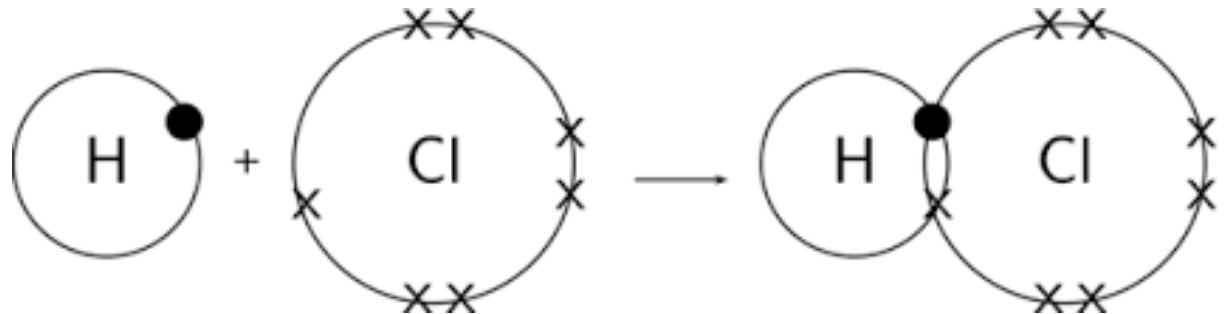
Example 1



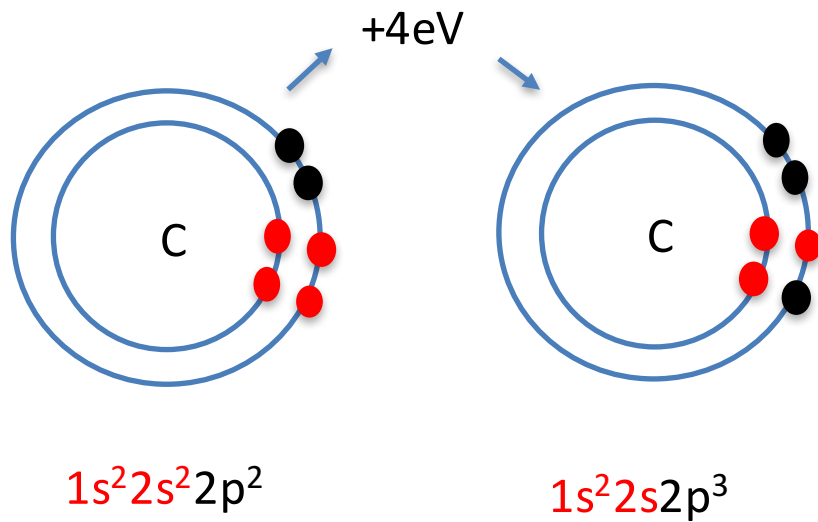
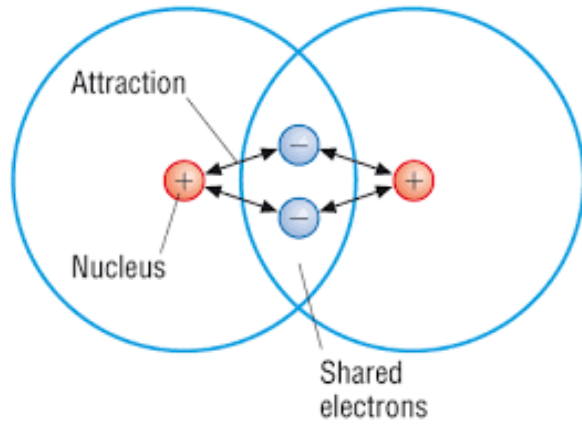
Example 2



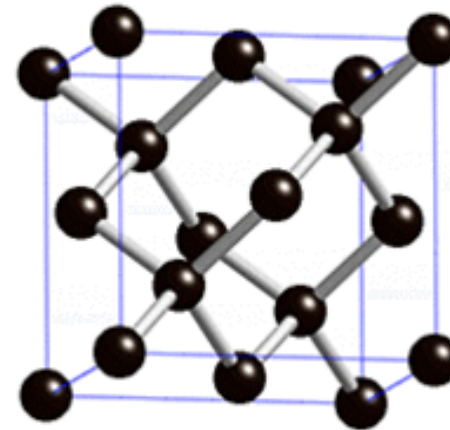
Example 3



Covalent Crystals

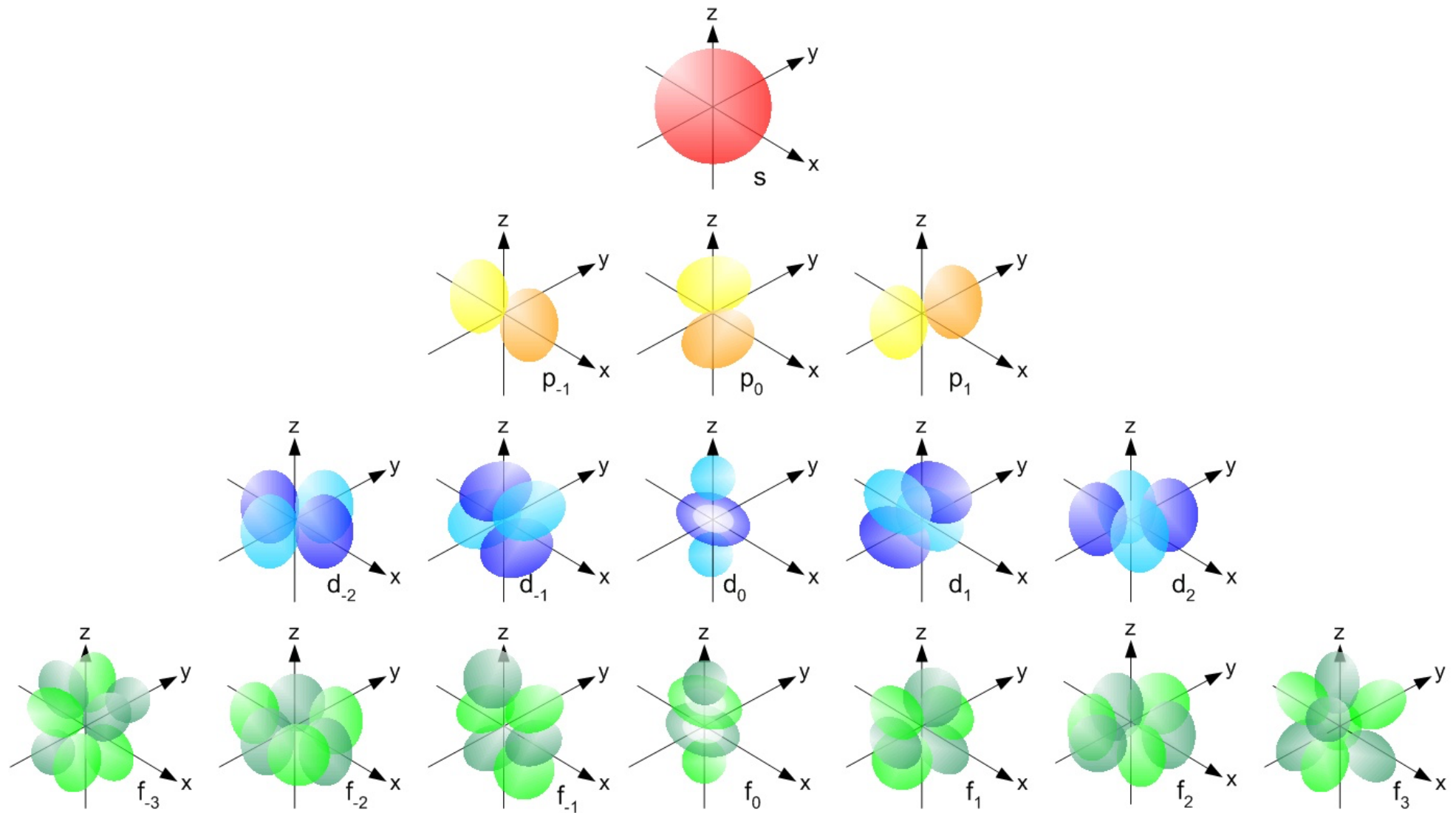


Diamond structure

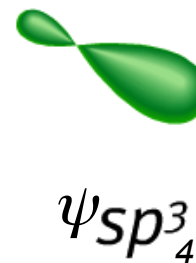
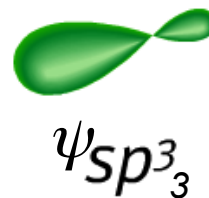
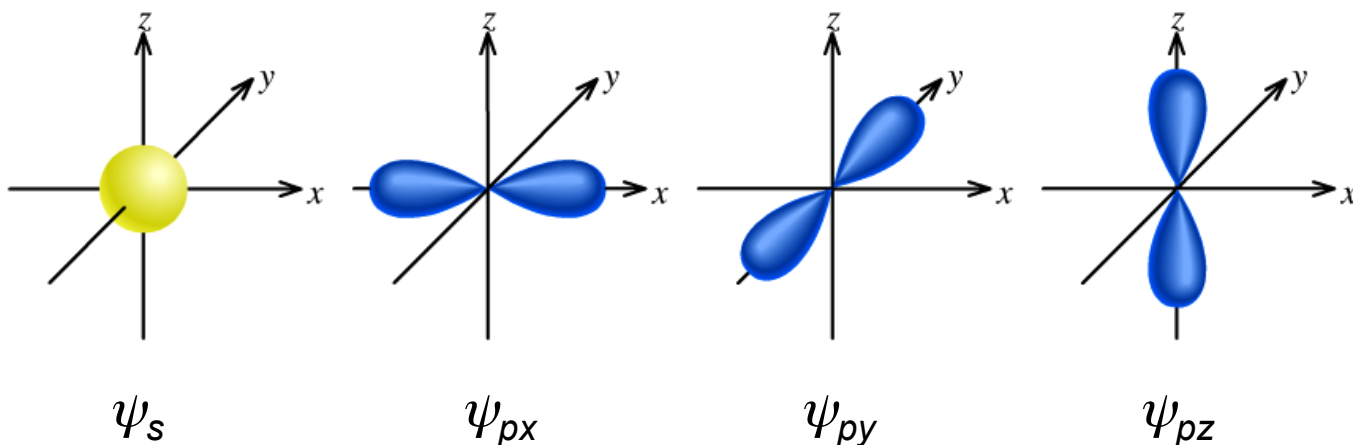


4 covalent bonds

Electronic orbitals



Orbital hybridization



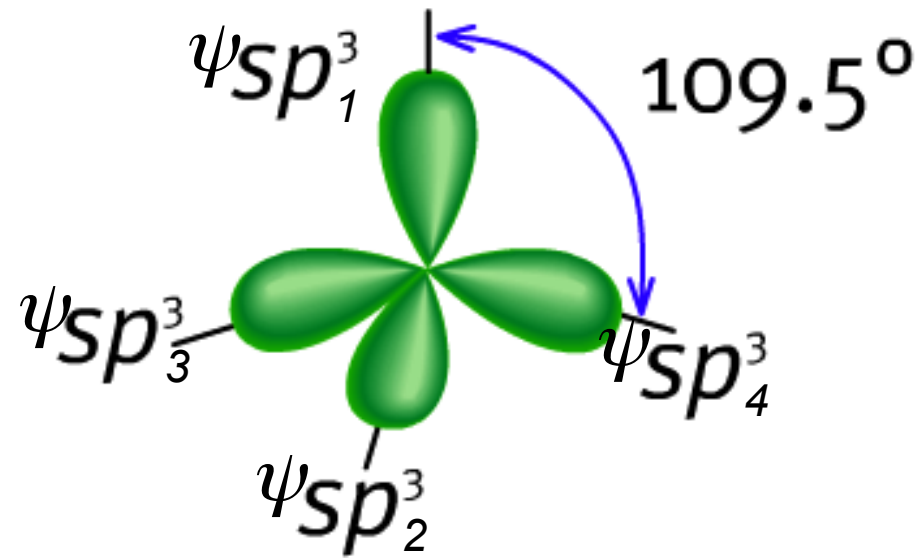
$$\frac{1}{2}(\psi_s + \psi_{px} + \psi_{py} + \psi_{pz})$$

$$\frac{1}{2}(\psi_s + \psi_{px} - \psi_{py} - \psi_{pz})$$

$$\frac{1}{2}(\psi_s - \psi_{px} + \psi_{py} - \psi_{pz})$$

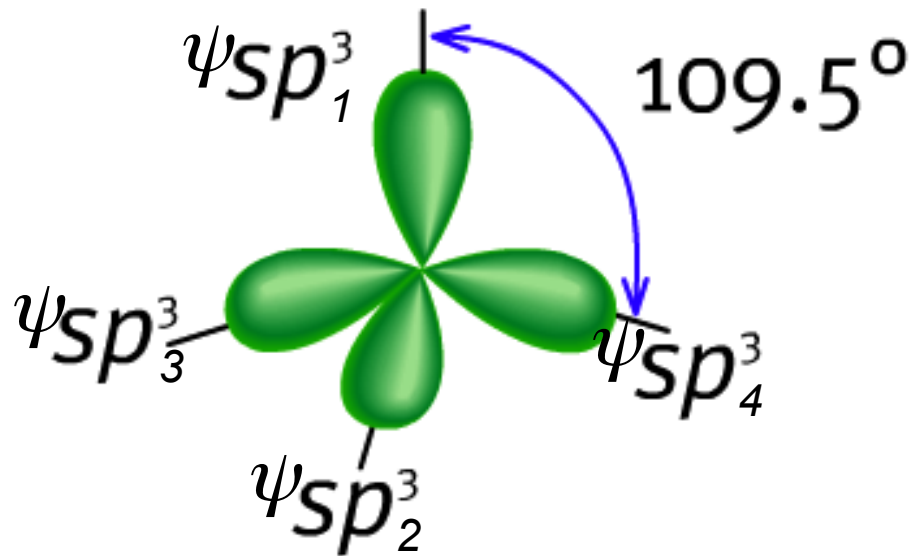
$$\frac{1}{2}(\psi_s - \psi_{px} - \psi_{py} + \psi_{pz})$$

Orbital hybridization

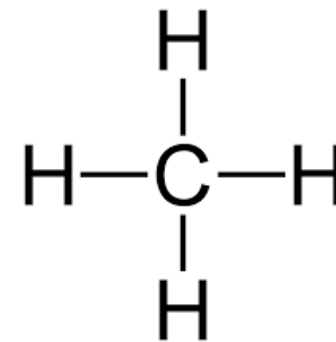
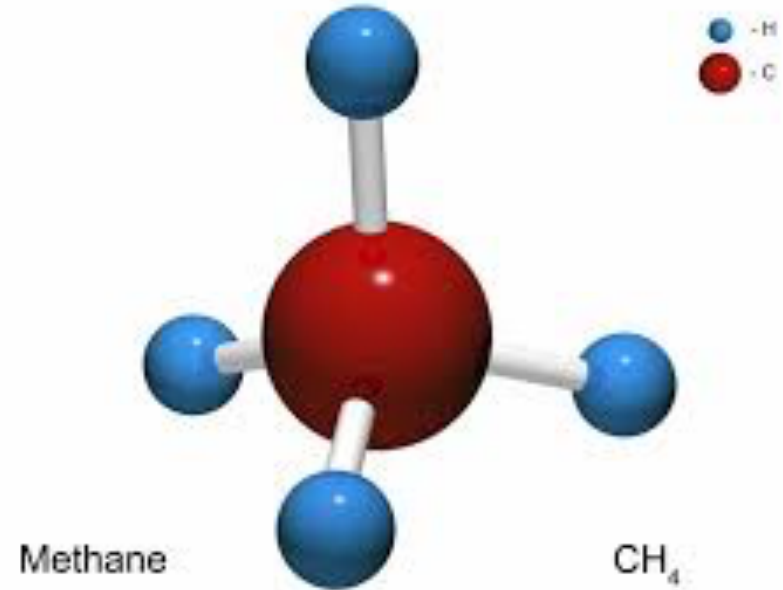


Tetraeder

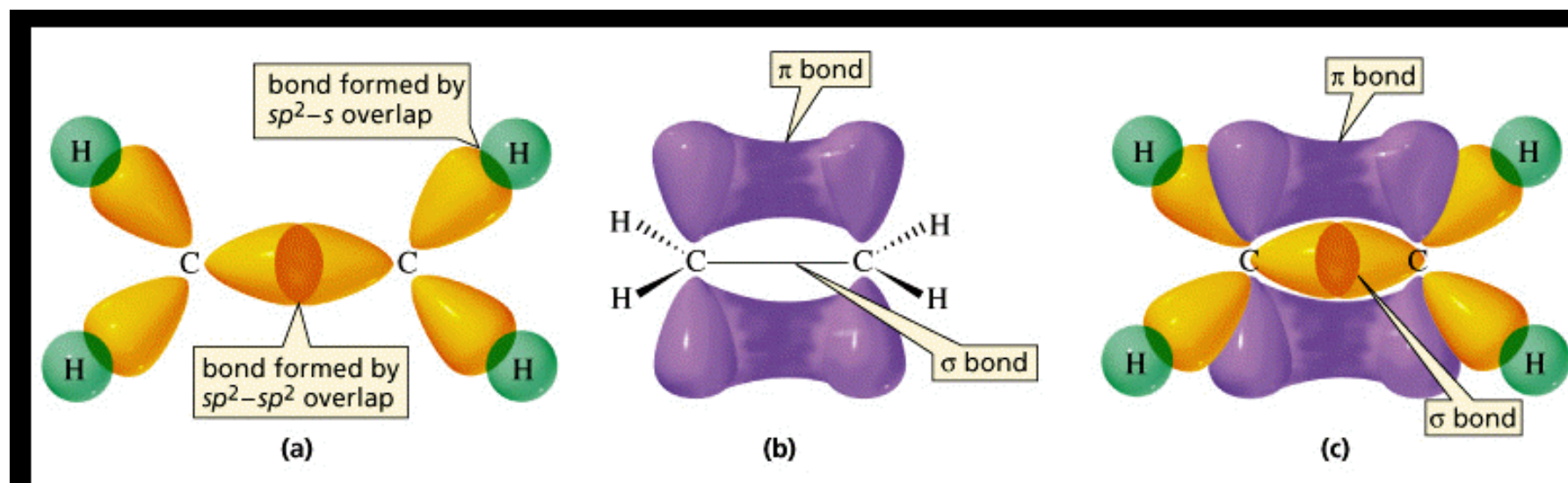
Orbital molecular theory: Example CH₄ (Methane)



Tetraeder

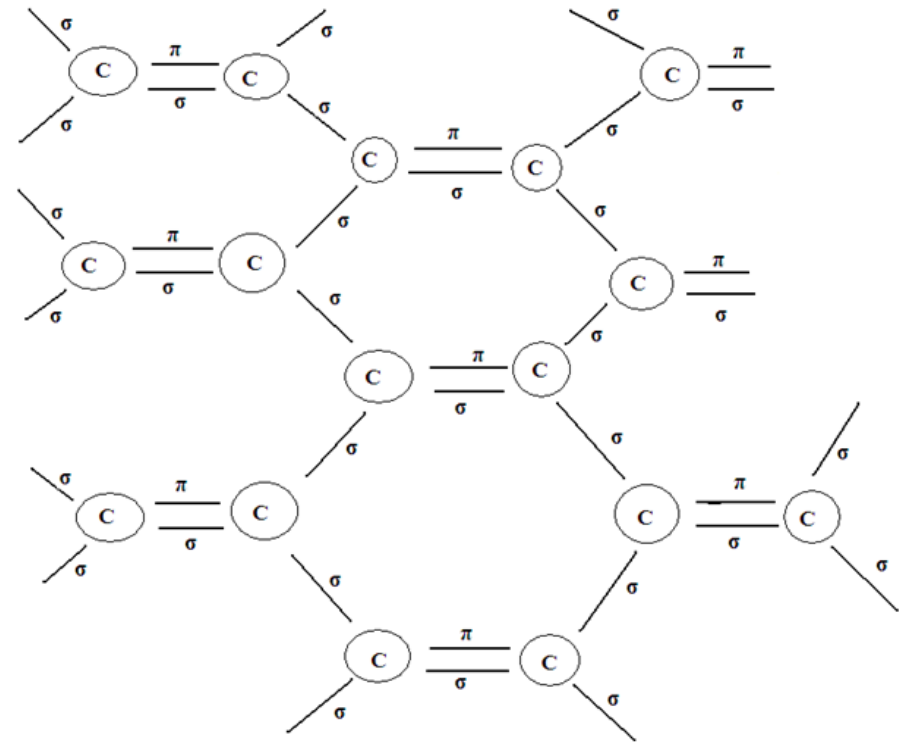
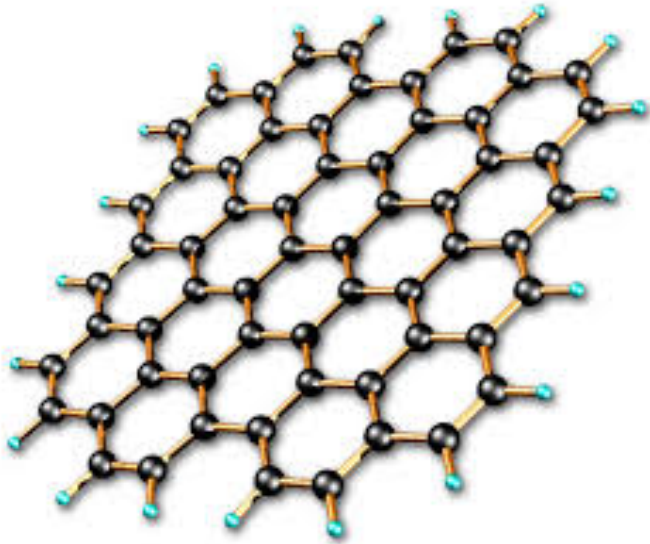


Orbital molecular theory: σ and π bonding

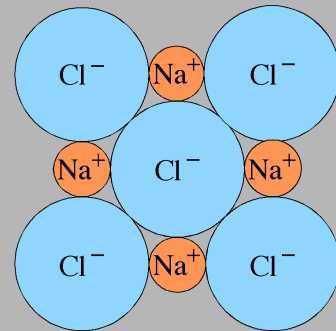


Graphene: σ and π bonding

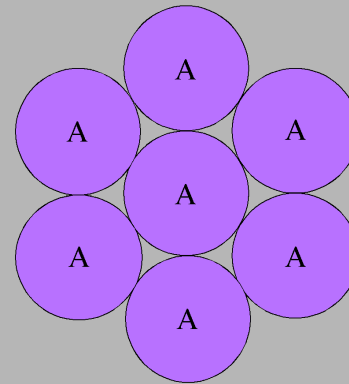
Graphene



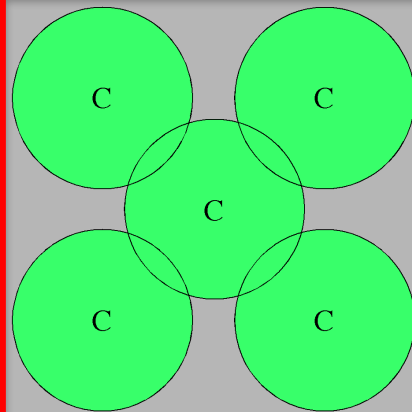
Today's lecture



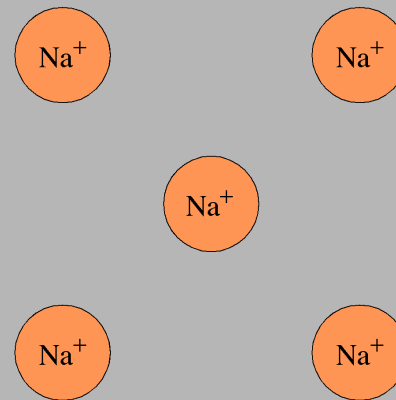
Natriumchlorid
(ionisch)



Kristallines Argon
(van der Waals)



Diamant
(kovalent)

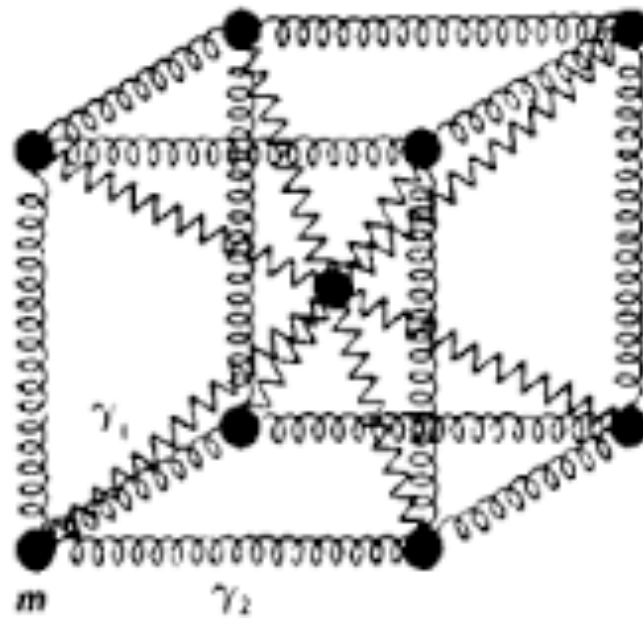


Natrium
(metallisch)

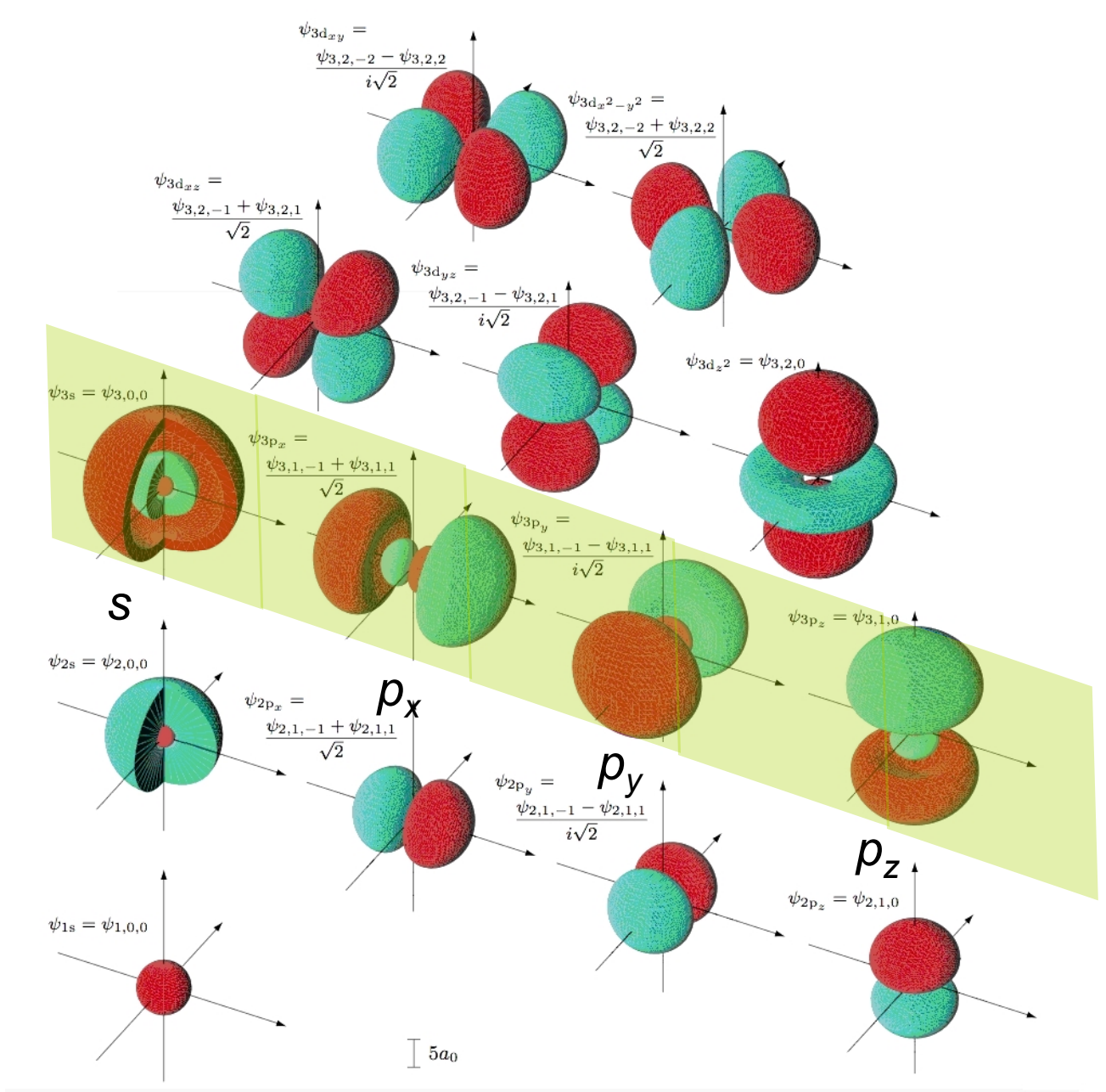
Summary

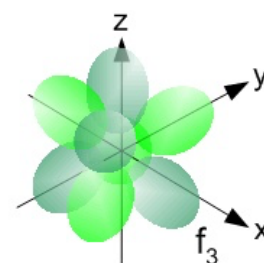
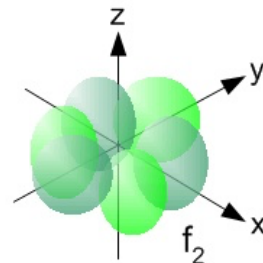
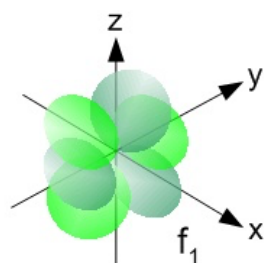
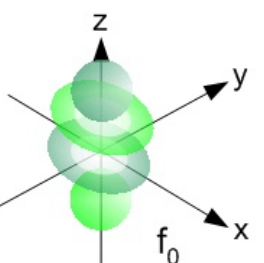
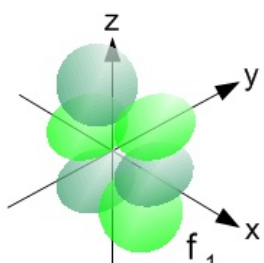
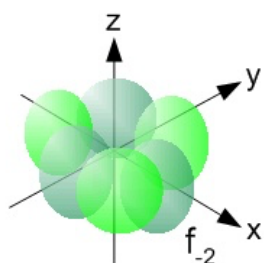
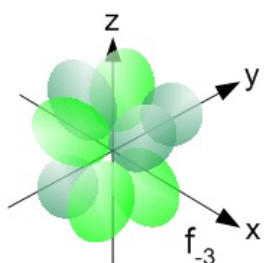
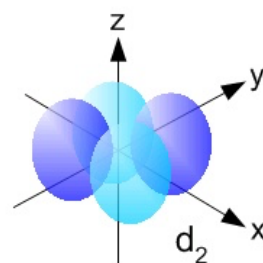
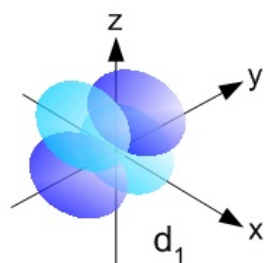
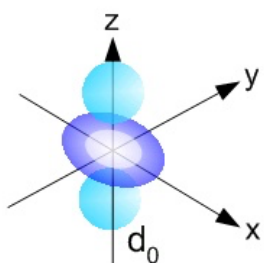
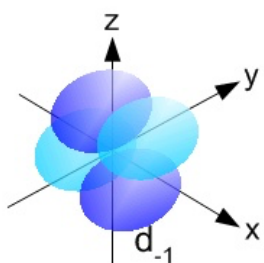
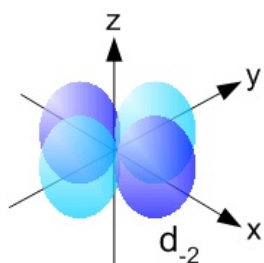
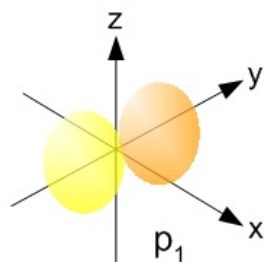
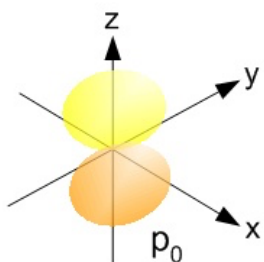
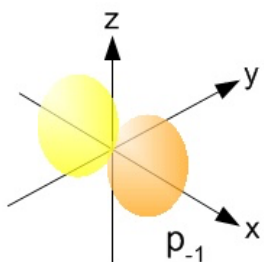
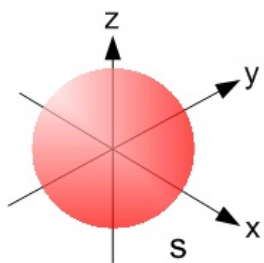
Bindungstyp	Beispiel	Bindungsenergie (eV)
Ionisch	NaCl	8.23
	LiF	10.92
Van-der-Waals	Ar	0.080
	Kr	0.116
Kovalent	Diamant	7.36
	Si	4.64
Metallisch	Na	1.13
	Fe	4.29
	W	8.66
Wasserstoff-Brücken	H ₂ O	0.52
	HF	0.30

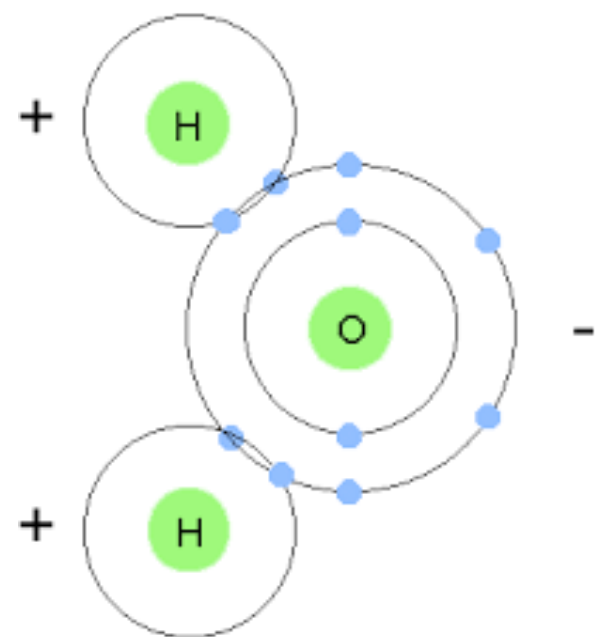
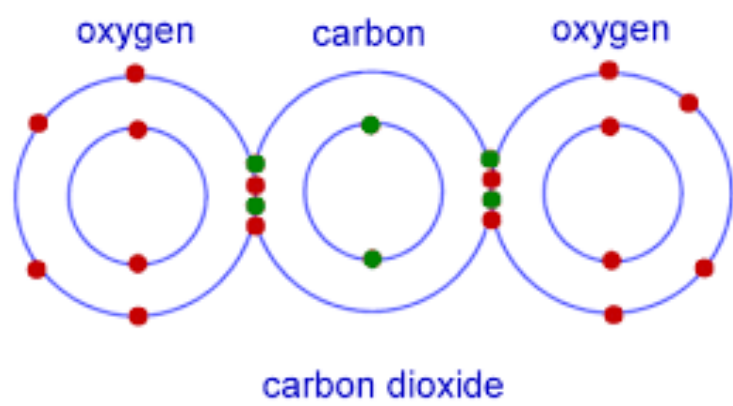
Next weeks lecture



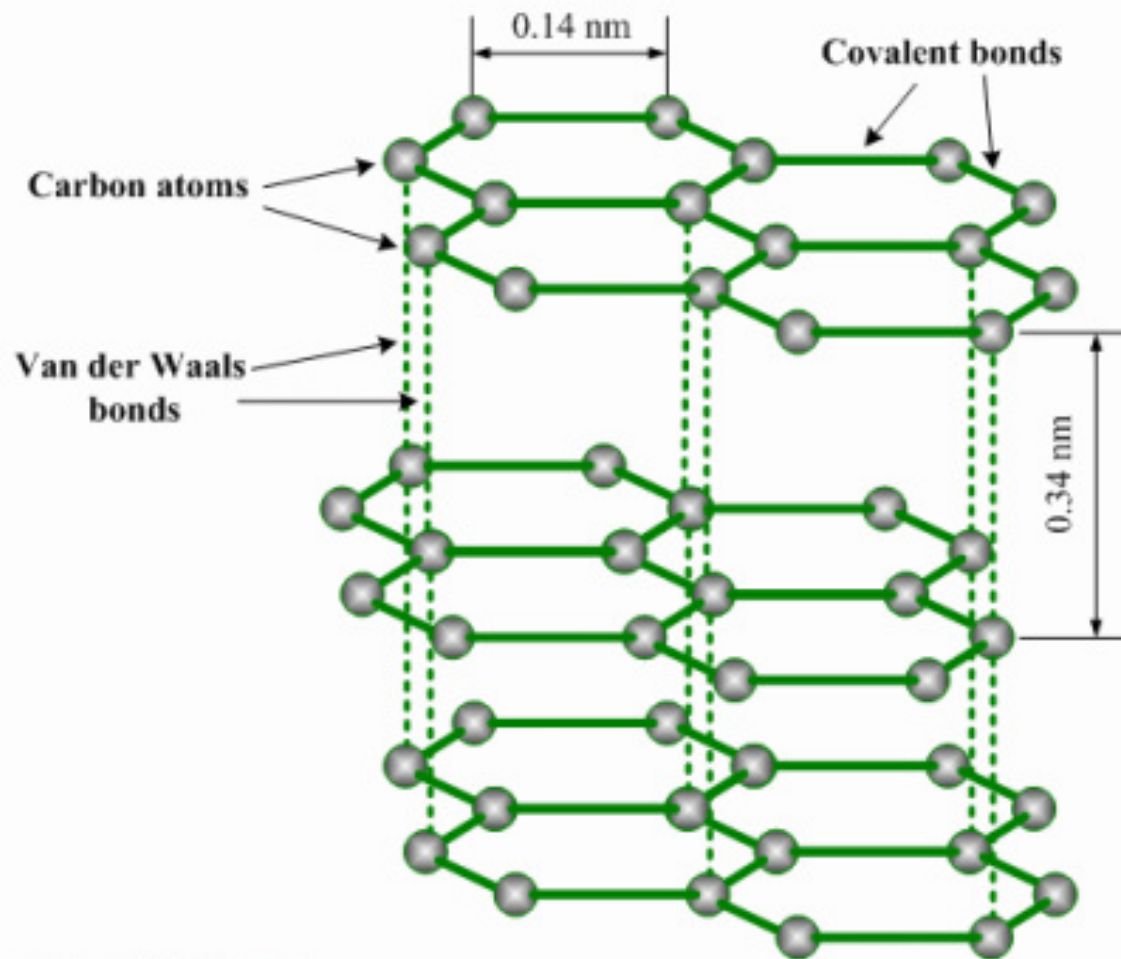
Lattice vibrations

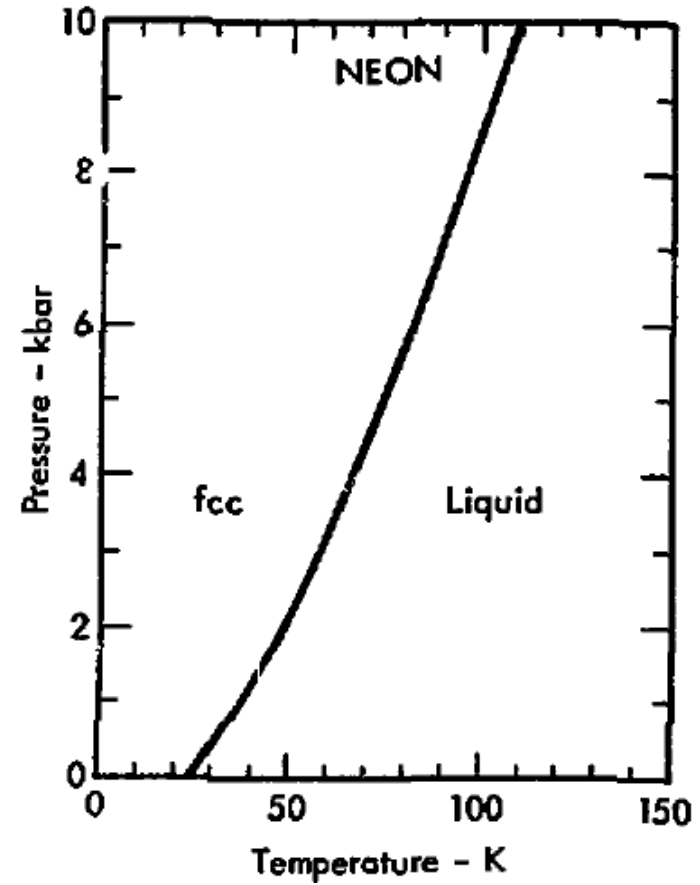
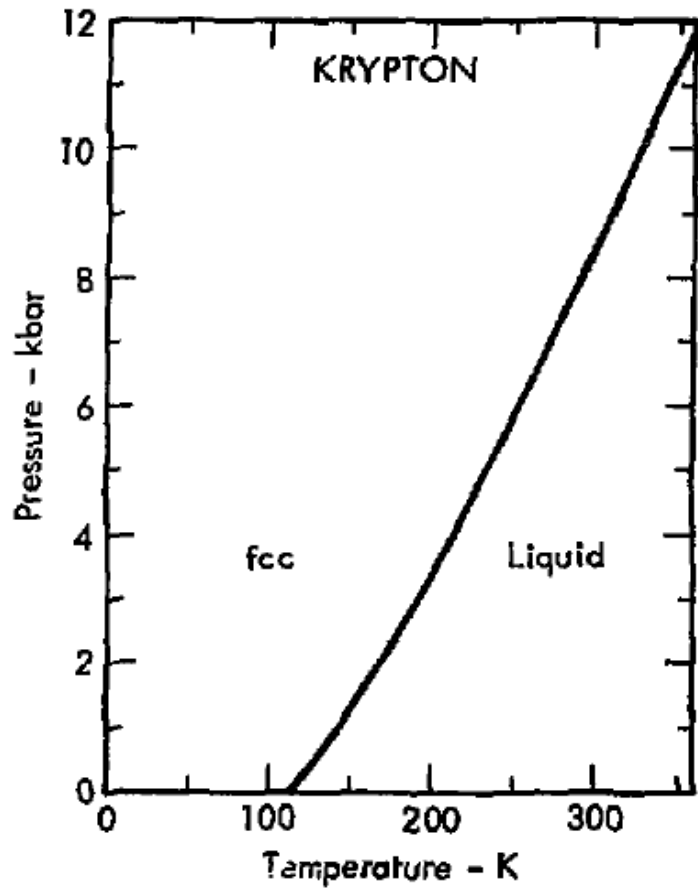






Graphite structure





[https://commons.wikimedia.org/wiki/File:Phase_diagram_of_krypton_\(1975\).png](https://commons.wikimedia.org/wiki/File:Phase_diagram_of_krypton_(1975).png)