

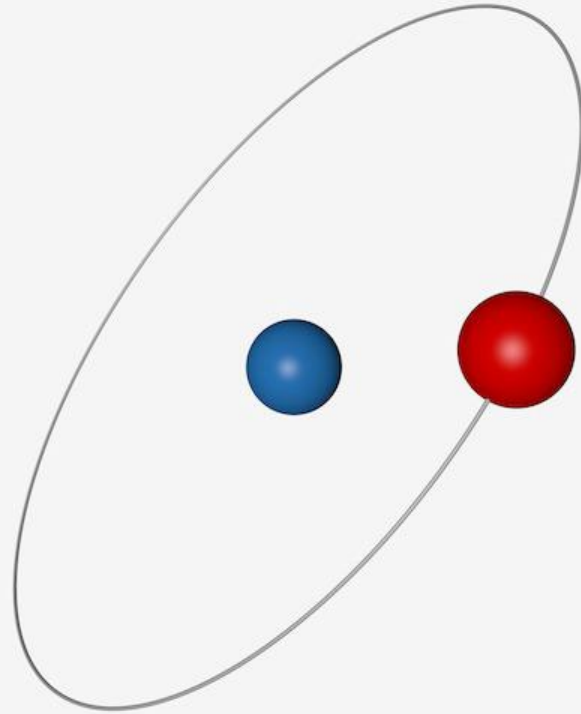
Working Principle of a Semiconductor Based Solar Cell

Band Gap I - Electrons in Atoms

Week 2.2.1

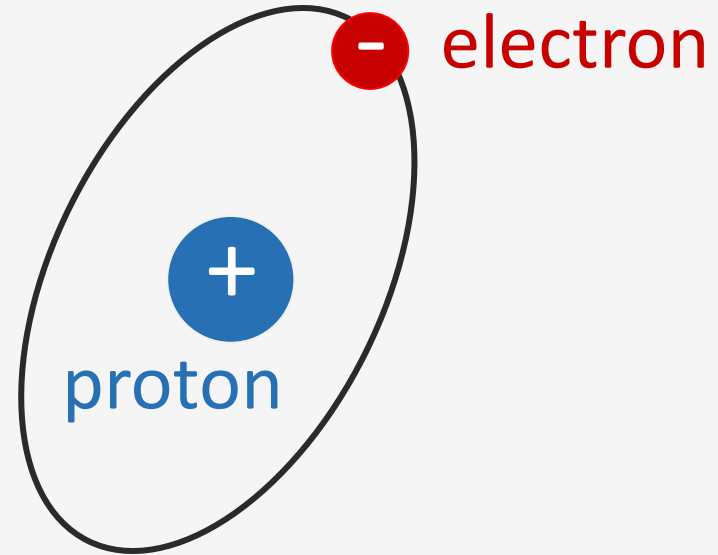
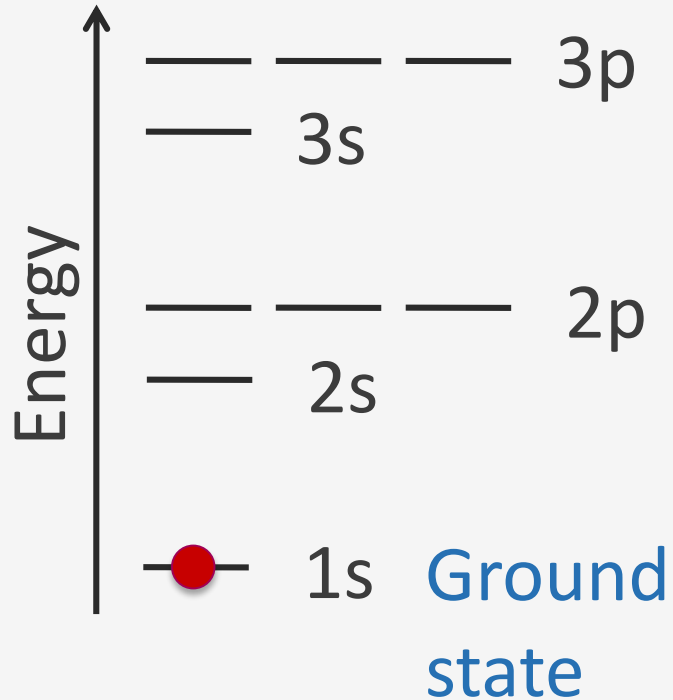
Arno Smets

Hydrogen

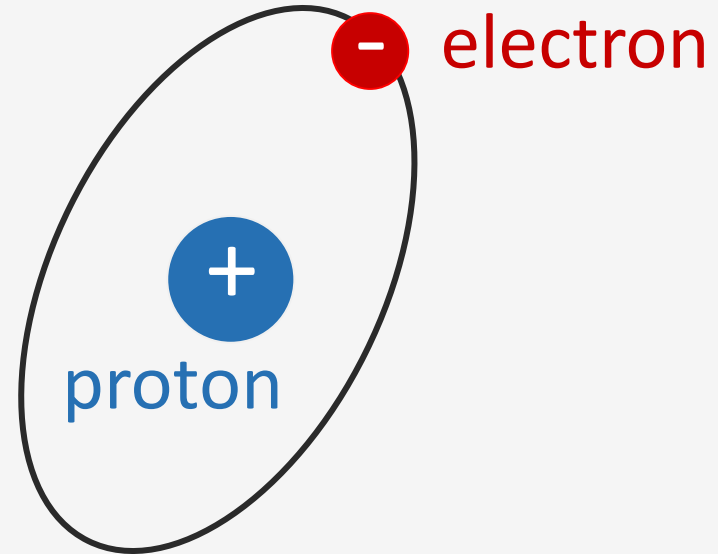
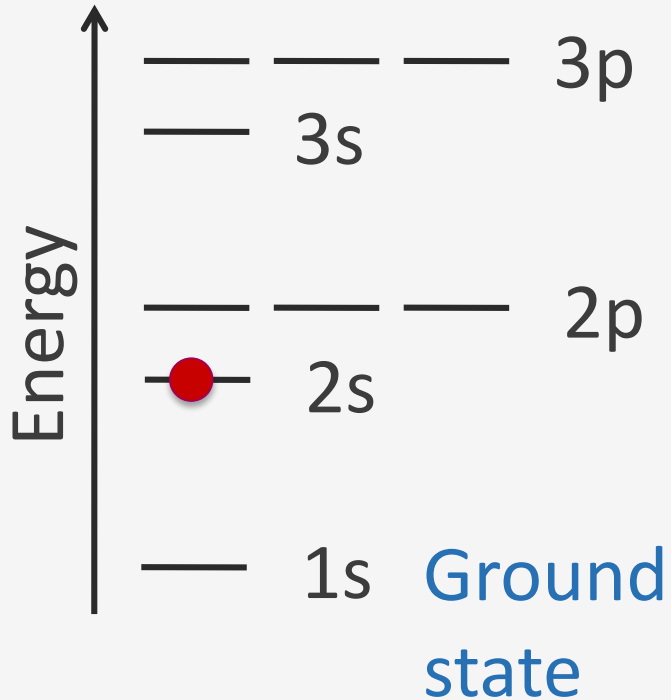


-  Proton (+)
-  Electron (-)

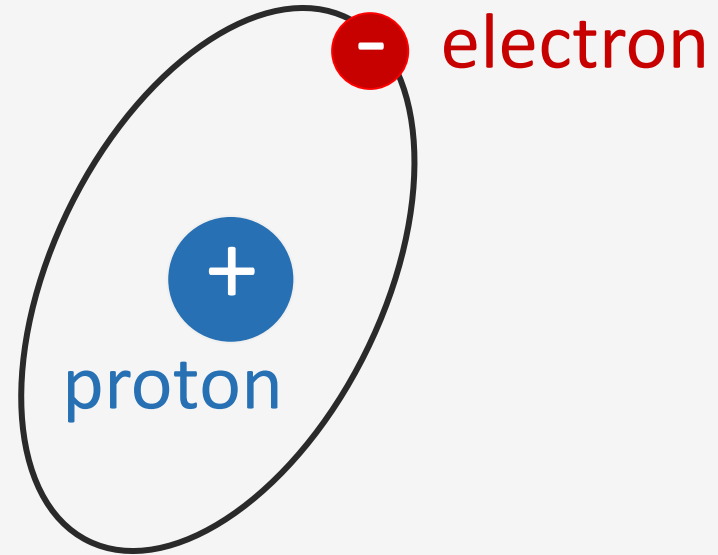
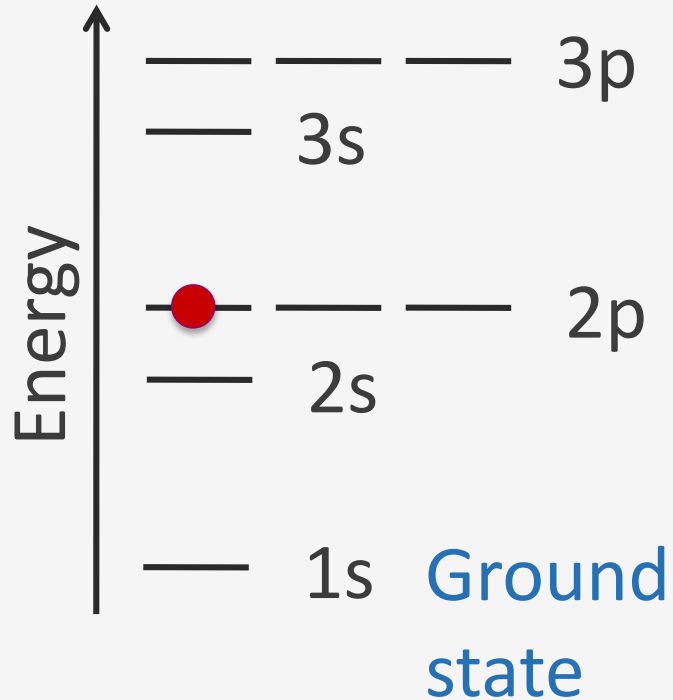
How strong are electrons bonded: **the H atom**



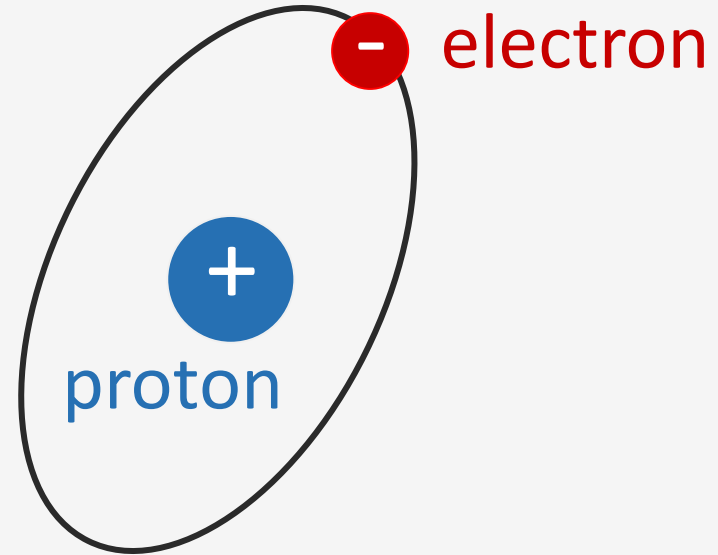
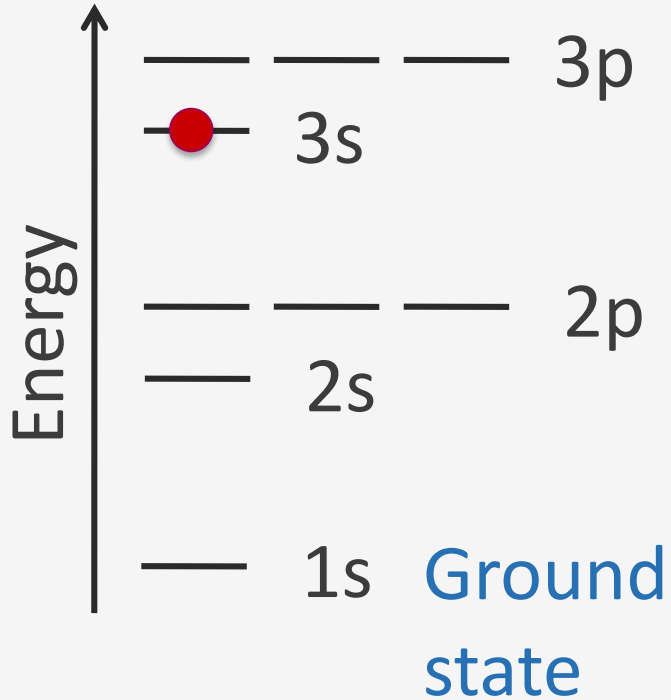
How strong are electrons bonded: **the H atom**



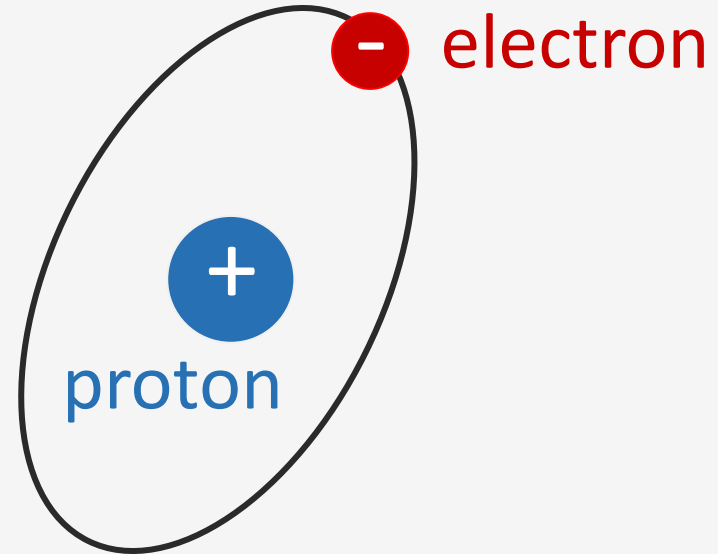
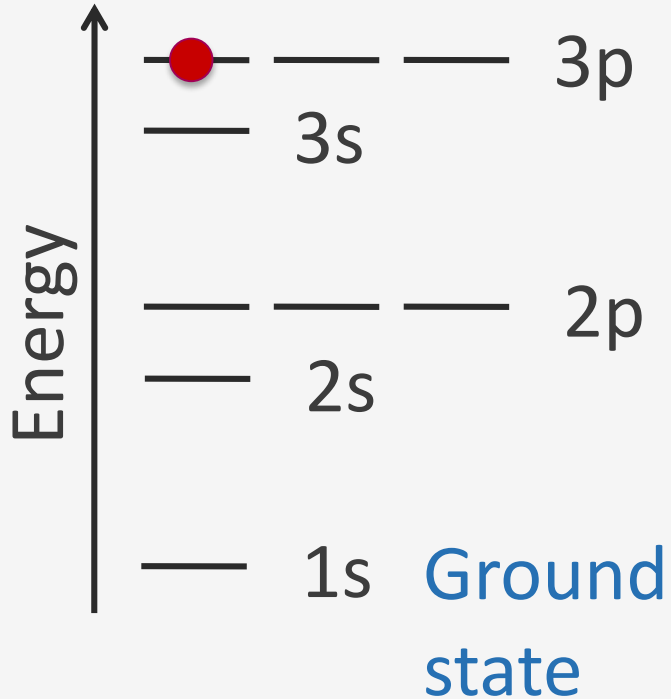
How strong are electrons bonded: **the H atom**



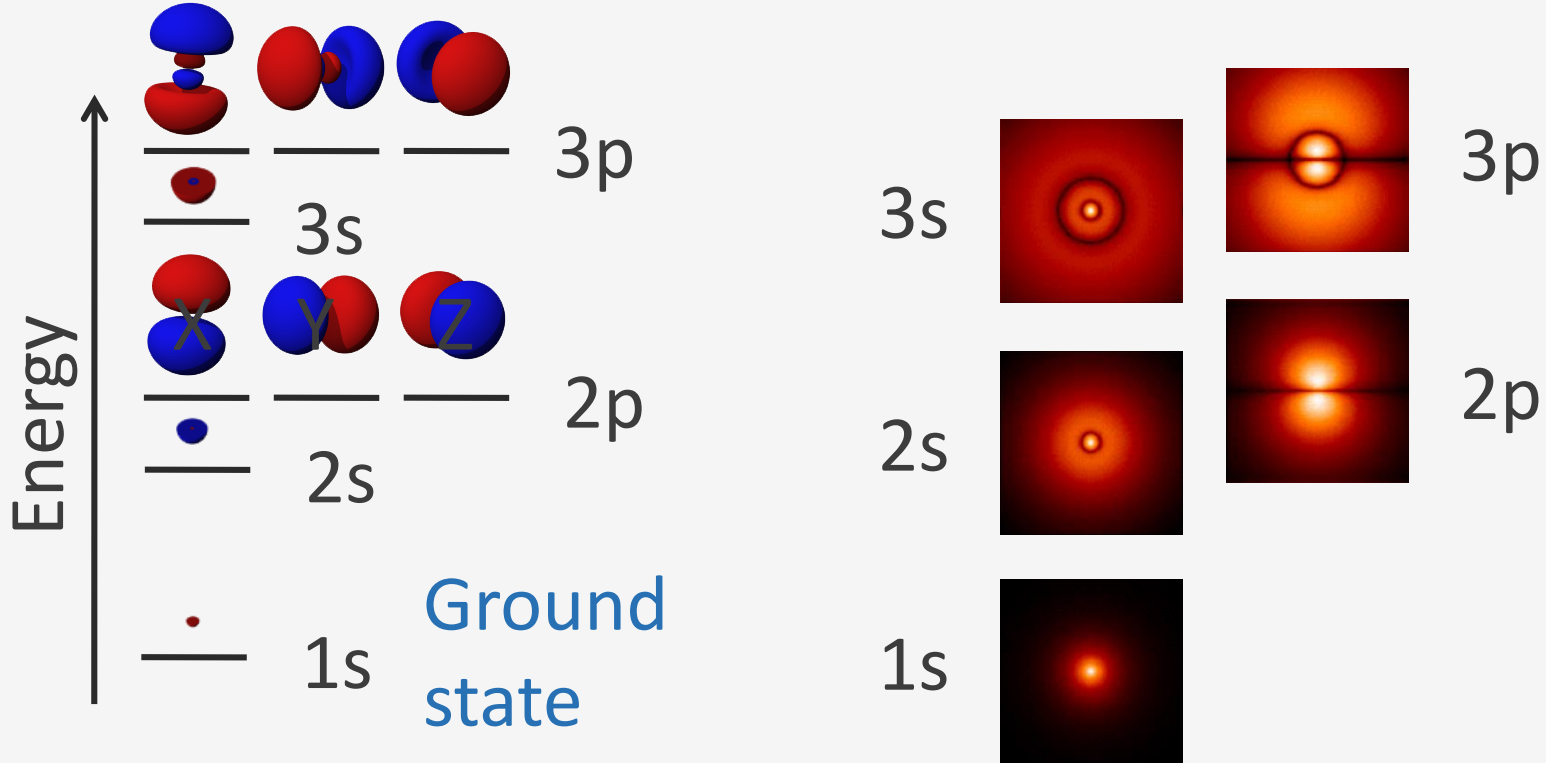
How strong are electrons bonded: **the H atom**



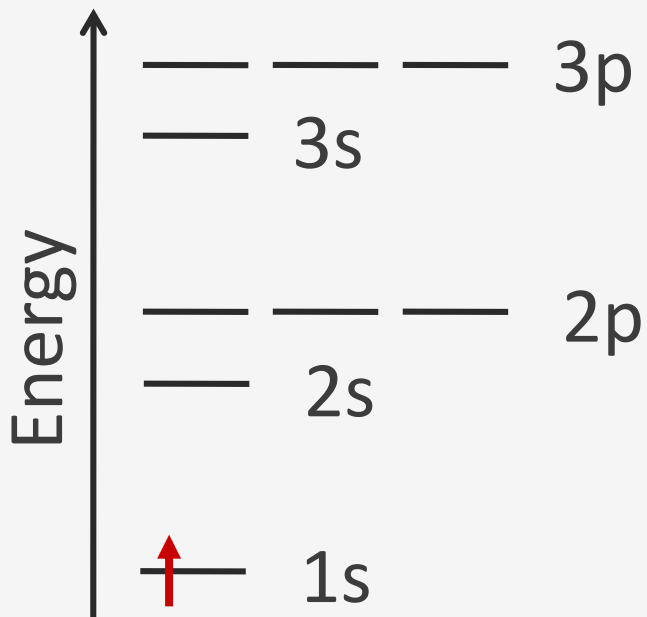
How strong are electrons bonded: **the H atom**



How strong are electrons bonded: **the H atom**



How strong are electrons bonded



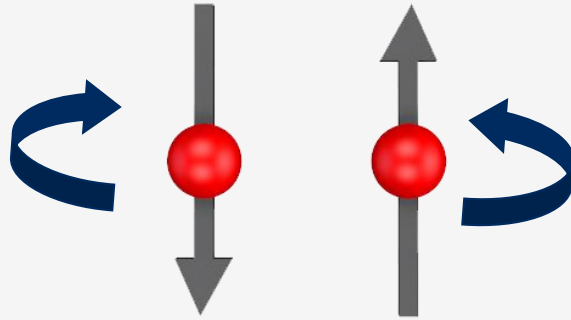
Periodic Table of the Elements

 hydrogen
 alkali metals
 alkali earth metals
 transition metals

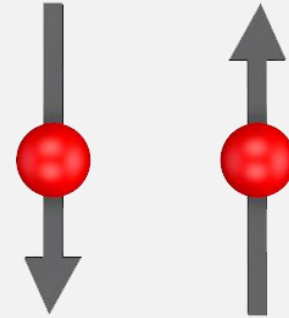
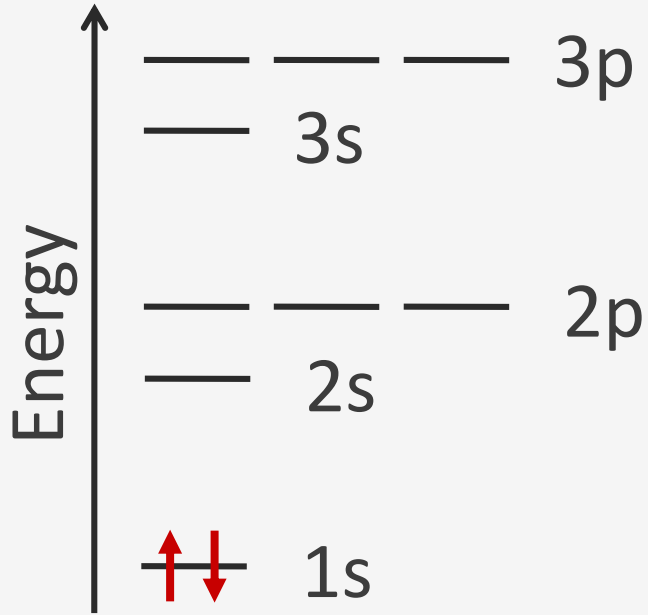
 hydrogen
 alkali metals
 alkali earth metals
 transition metals

1 H																	2 He																												
3 Li	4 Be											5 B	6 C	7 N	8 O	9 F	10 Ne																												
11 Na	12 Mg											13 Al	14 Si	15 P	16 S	17 Cl	18 Ar																												
19 K	20 Ca	21 Sc	22 Ti	23 V	24 Cr	25 Mn	26 Fe	27 Co	28 Ni	29 Cu	30 Zn	31 Ga	32 Ge	33 As	34 Se	35 Br	36 Kr																												
37 Rb	38 Sr	39 Y	40 Zr	41 Nb	42 Mo	43 Tc	44 Ru	45 Rh	46 Pd	47 Ag	48 Cd	49 In	50 Sn	51 Sb	52 Te	53 I	54 Xe																												
55 Cs	56 Ba	57 La	72 Hf	73 Ta	74 W	75 Re	76 Os	77 Ir	78 Pt	79 Au	80 Hg	81 Tl	82 Pb	83 Bi	84 Po	85 At	86 Rn																												
87 Fr	88 Ra	89 Ac	104 Rf	105 Db	106 Sg	107 Bh	108 Hs	109 Mt	110 Ds	111 Rg																																			
<table border="1" style="border-collapse: collapse; text-align: center; width: 100%;"> <tbody> <tr> <td>58 Ce</td><td>59 Pr</td><td>60 Nd</td><td>61 Pm</td><td>62 Sm</td><td>63 Eu</td><td>64 Gd</td><td>65 Tb</td><td>66 Dy</td><td>67 Ho</td><td>68 Er</td><td>69 Tm</td><td>70 Yb</td><td>71 Lu</td> </tr> <tr> <td>90 Th</td><td>91 Pa</td><td>92 U</td><td>93 Np</td><td>94 Pu</td><td>95 Am</td><td>96 Cm</td><td>97 Bk</td><td>98 Cf</td><td>99 Es</td><td>100 Fm</td><td>101 Md</td><td>102 No</td><td>103 Lr</td> </tr> </tbody> </table>																		58 Ce	59 Pr	60 Nd	61 Pm	62 Sm	63 Eu	64 Gd	65 Tb	66 Dy	67 Ho	68 Er	69 Tm	70 Yb	71 Lu	90 Th	91 Pa	92 U	93 Np	94 Pu	95 Am	96 Cm	97 Bk	98 Cf	99 Es	100 Fm	101 Md	102 No	103 Lr
58 Ce	59 Pr	60 Nd	61 Pm	62 Sm	63 Eu	64 Gd	65 Tb	66 Dy	67 Ho	68 Er	69 Tm	70 Yb	71 Lu																																
90 Th	91 Pa	92 U	93 Np	94 Pu	95 Am	96 Cm	97 Bk	98 Cf	99 Es	100 Fm	101 Md	102 No	103 Lr																																

Electron spin

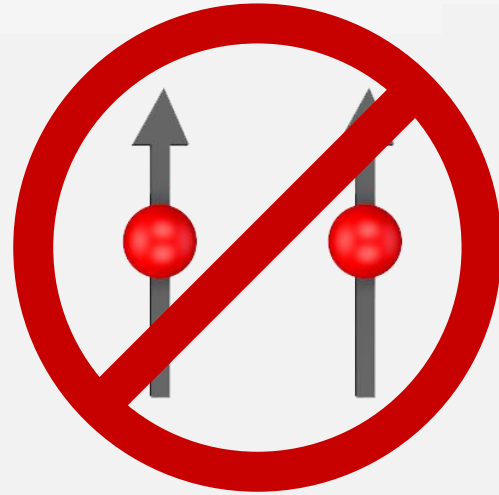
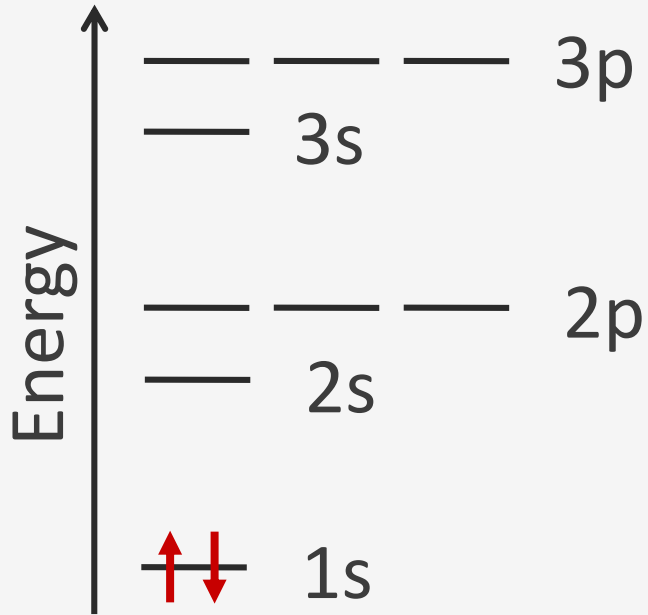


How strong are electrons bonded:



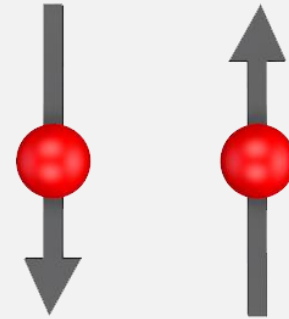
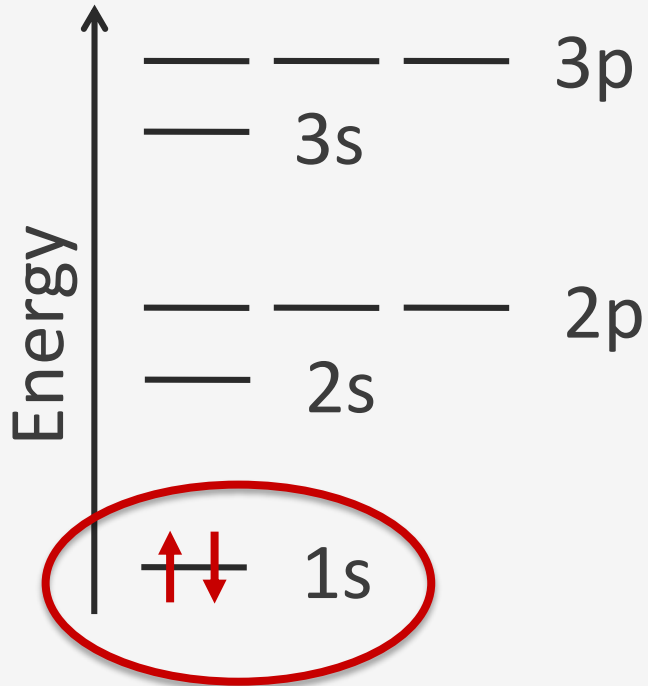
Pauli principle: two identical electrons can not occupy the same quantum state simultaneously.

Pauli's Exclusion Principle:



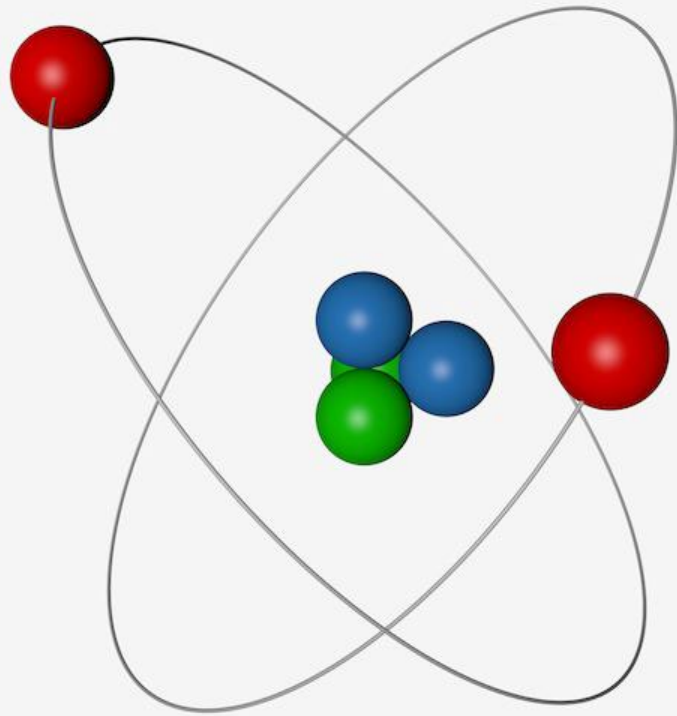
Pauli principle: two identical electrons can not occupy the same quantum state simultaneously.

How strong are electrons bonded:

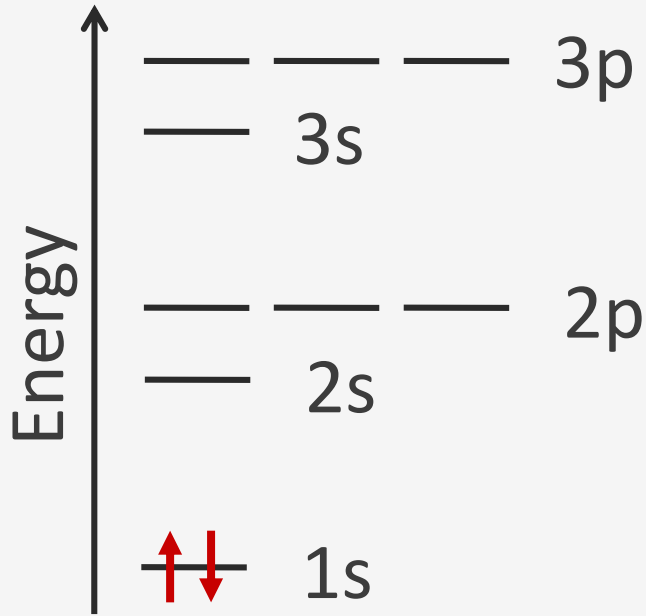


Pauli principle: two identical electrons can not occupy the same quantum state simultaneously.

Helium



How strong are electrons bonded

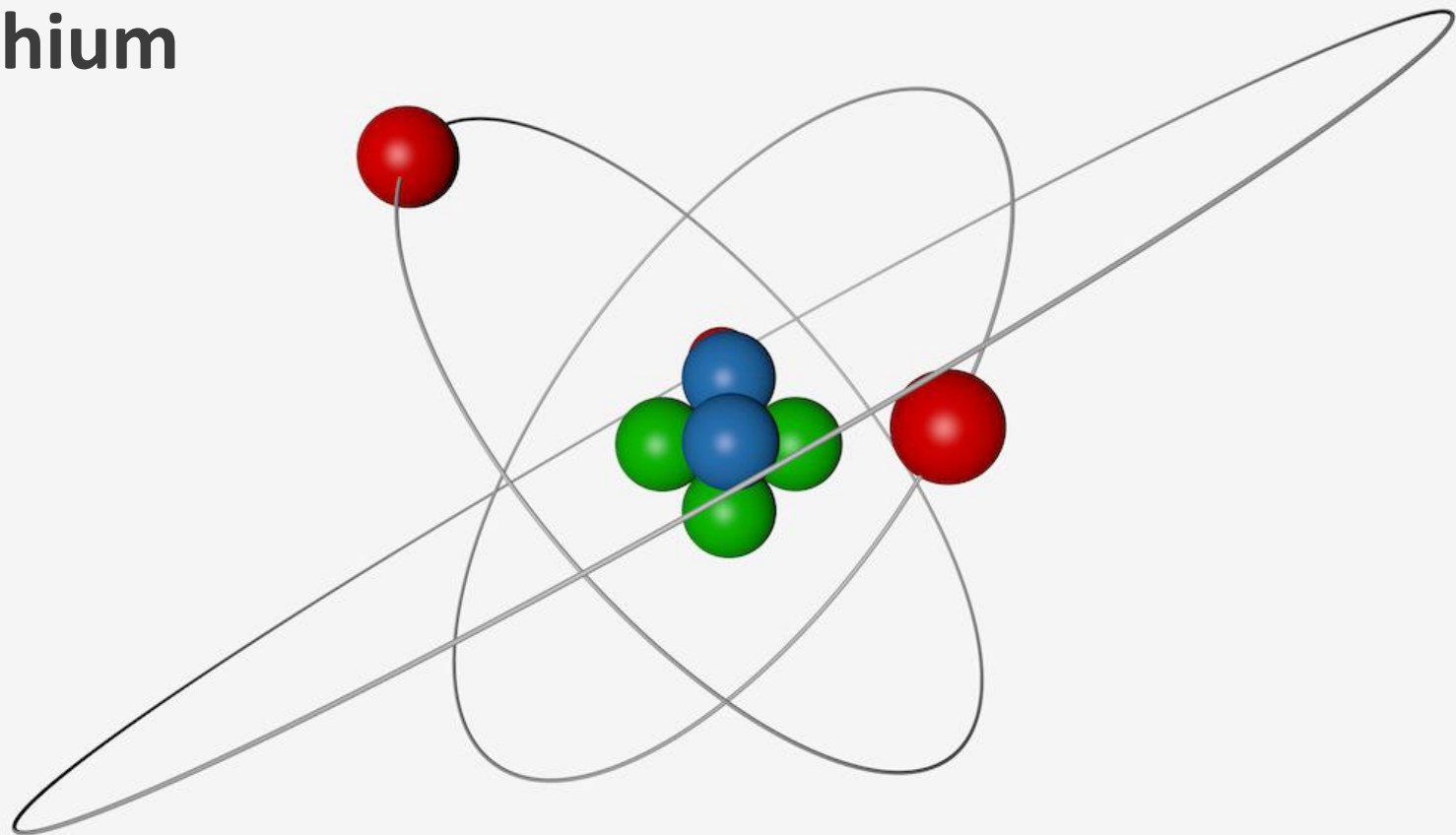


Periodic Table of the Elements

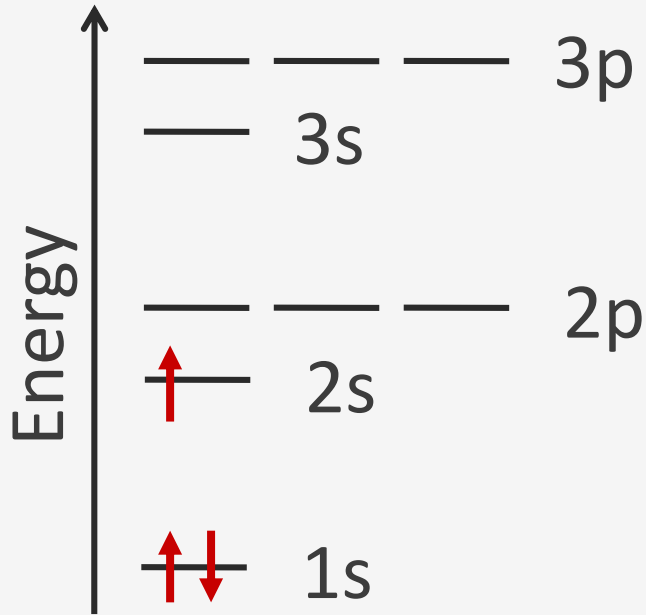
- | | |
|---------------------|---------------------|
| hydrogen | hydrogen |
| alkali metals | alkali metals |
| alkali earth metals | alkali earth metals |
| transition metals | transition metals |



Lithium



How strong are electrons bonded

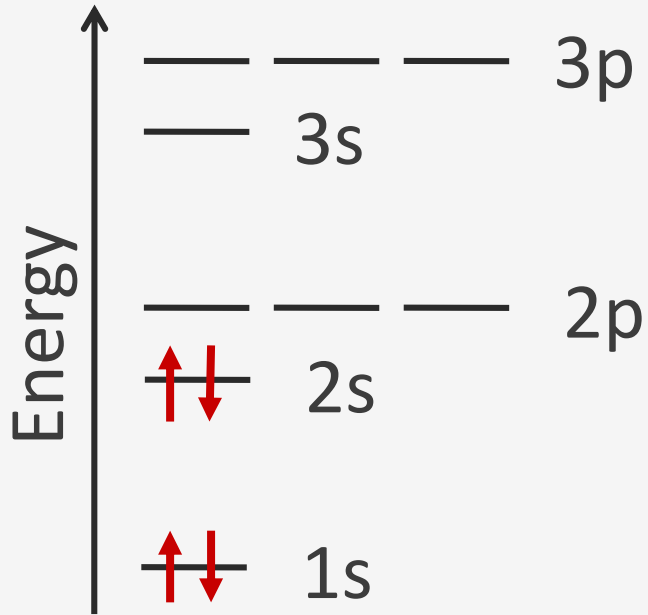


Periodic Table of the Elements

- | | |
|---------------------|---------------------|
| hydrogen | hydrogen |
| alkali metals | alkali metals |
| alkali earth metals | alkali earth metals |
| transition metals | transition metals |



How strong are electrons bonded



1 H	
3 Li	4 Be

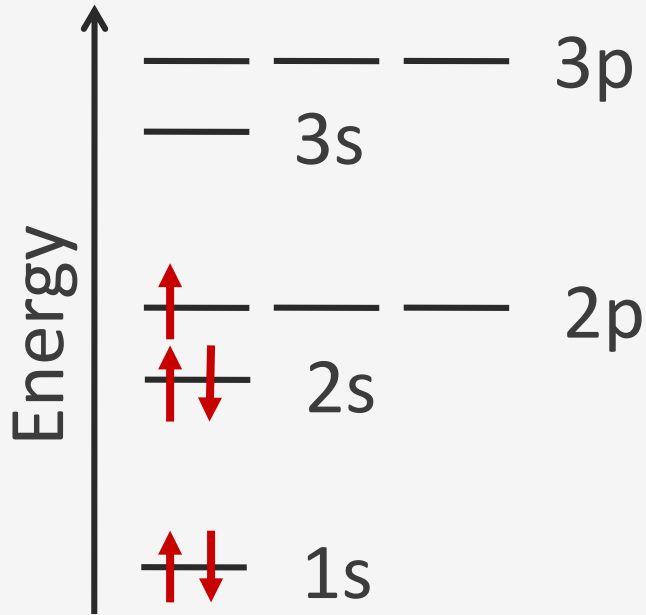
Periodic Table of the Elements

hydrogen	hydrogen
alkali metals	alkali metals
alkali earth metals	alkali earth metals
transition metals	transition metals

2 He



How strong are electrons bonded

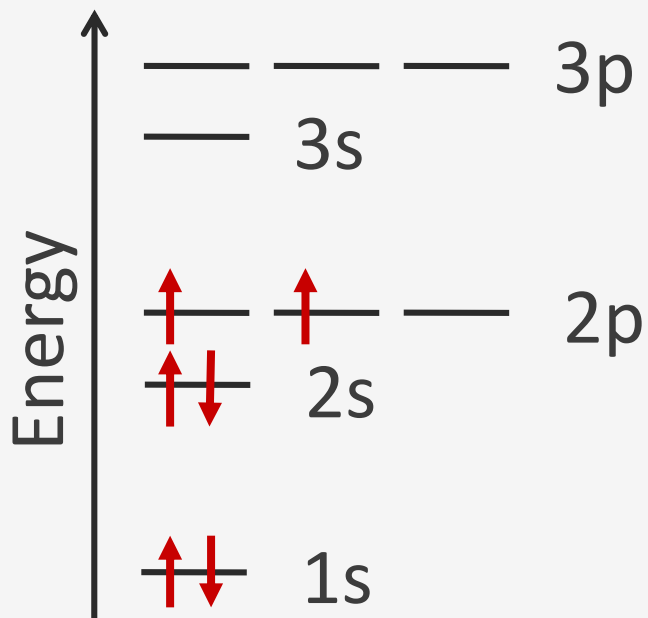


Periodic Table of the Elements

- hydrogen
- alkali metals
- alkali earth metals
- transition metals
- hydrogen
- alkali metals
- alkali earth metals
- transition metals



How strong are electrons bonded



1 H	
3 Li	4 Be

Periodic Table of the Elements

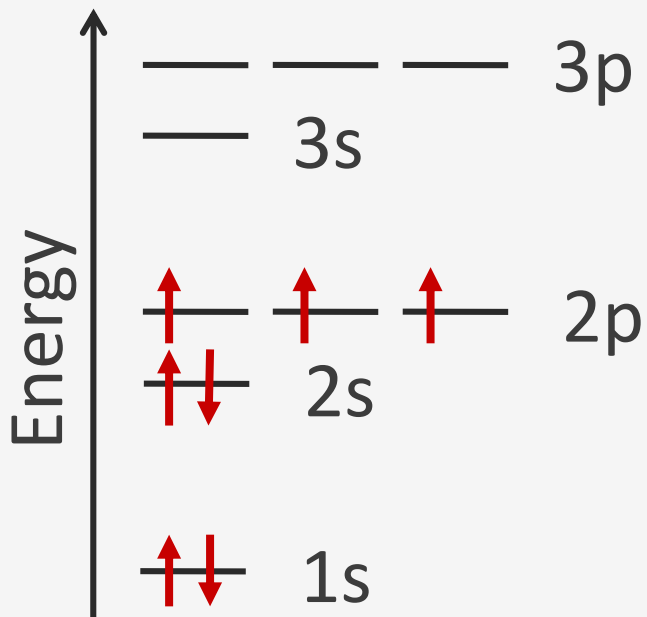
hydrogen	hydrogen
alkali metals	alkali metals
alkali earth metals	alkali earth metals
transition metals	transition metals

5 B	6 C
--------	--------

2 He



How strong are electrons bonded



¹ H	
³ Li	⁴ Be

Periodic Table of the Elements

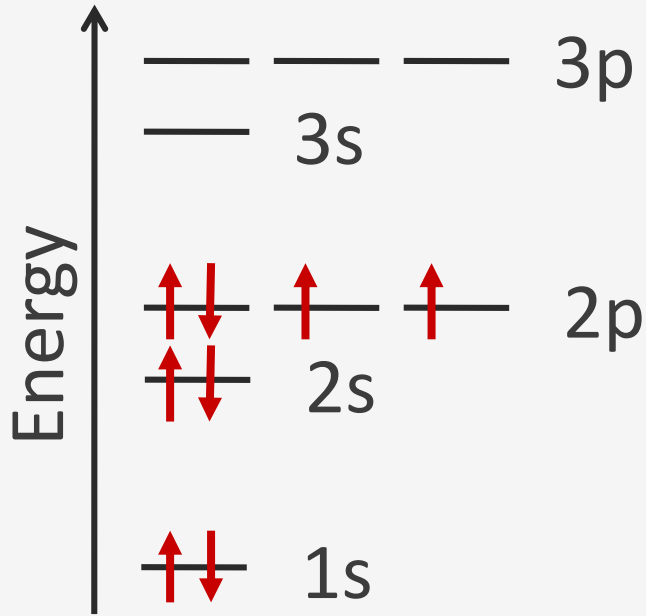
hydrogen	hydrogen
alkali metals	alkali metals
alkali earth metals	alkali earth metals
transition metals	transition metals

⁵ B	⁶ C	⁷ N
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² He



How strong are electrons bonded



1 H	
3 Li	4 Be

Periodic Table of the Elements

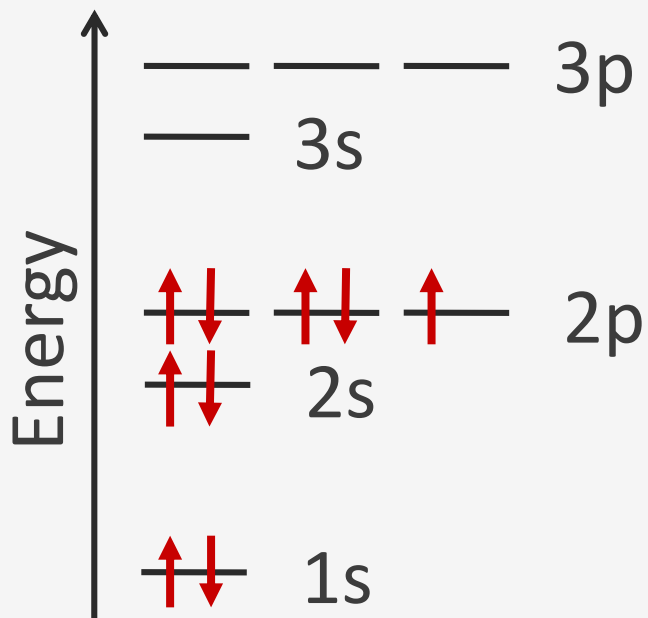
hydrogen	hydrogen
alkali metals	alkali metals
alkali earth metals	alkali earth metals
transition metals	transition metals

5 B	6 C	7 N	8 O
--------	--------	--------	--------

2 He



How strong are electrons bonded



1 H	
3 Li	4 Be

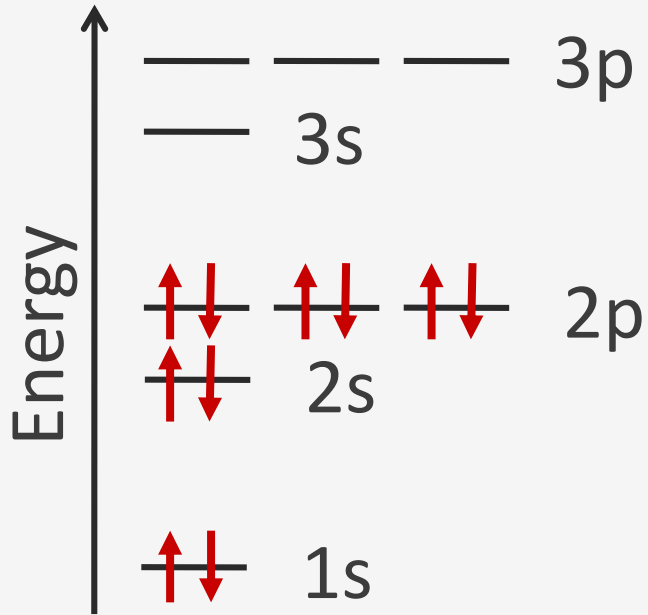
Periodic Table of the Elements

- hydrogen
- alkali metals
- alkali earth metals
- transition metals
- hydrogen
- alkali metals
- alkali earth metals
- transition metals

					2 He
5 B	6 C	7 N	8 O	9 F	



How strong are electrons bonded



1 H	
3 Li	4 Be

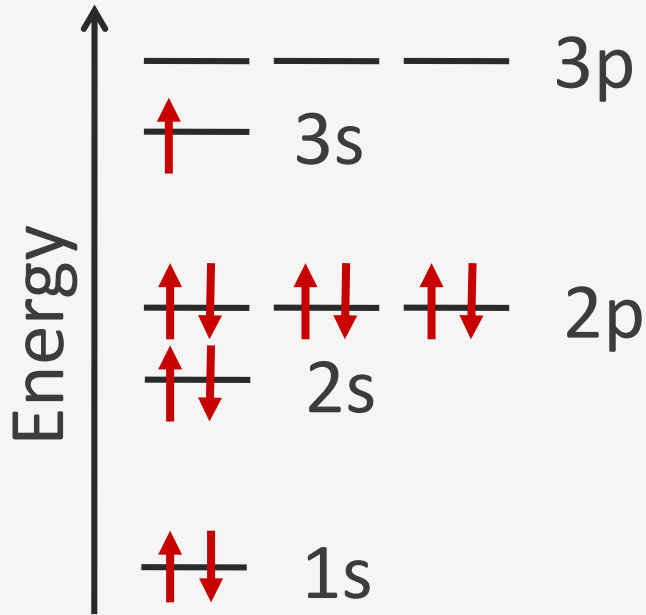
Periodic Table of the Elements

hydrogen	hydrogen
alkali metals	alkali metals
alkali earth metals	alkali earth metals
transition metals	transition metals

					2 He
5 B	6 C	7 N	8 O	9 F	10 Ne



How strong are electrons bonded



1 H	
3 Li	4 Be
11 Na	

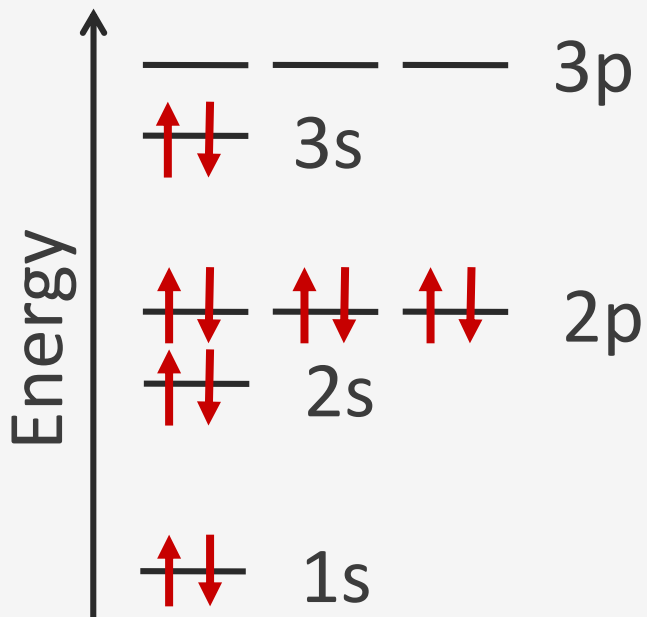
Periodic Table of the Elements

hydrogen	hydrogen
alkali metals	alkali metals
alkali earth metals	alkali earth metals
transition metals	transition metals

					2 He
5 B	6 C	7 N	8 O	9 F	10 Ne



How strong are electrons bonded



1 H	
3 Li	4 Be
11 Na	12 Mg

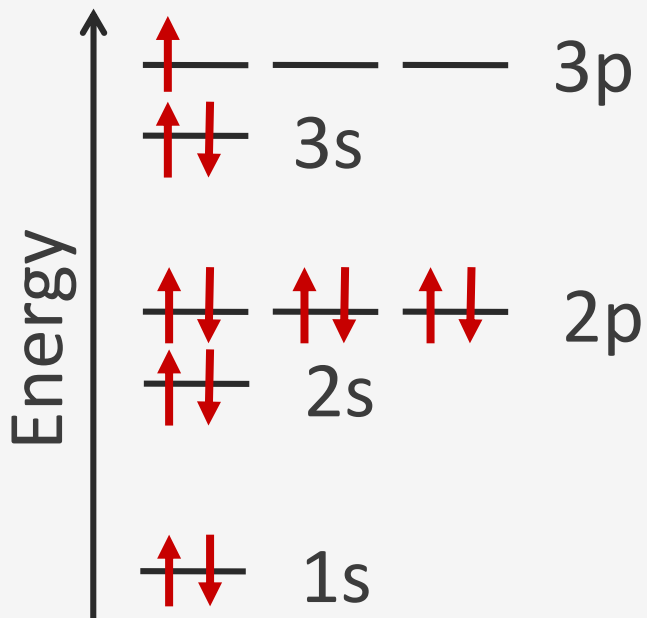
Periodic Table of the Elements

- hydrogen
- alkali metals
- alkali earth metals
- transition metals
- hydrogen
- alkali metals
- alkali earth metals
- transition metals

					2 He
5 B	6 C	7 N	8 O	9 F	10 Ne



How strong are electrons bonded



1 H	
3 Li	4 Be
11 Na	12 Mg

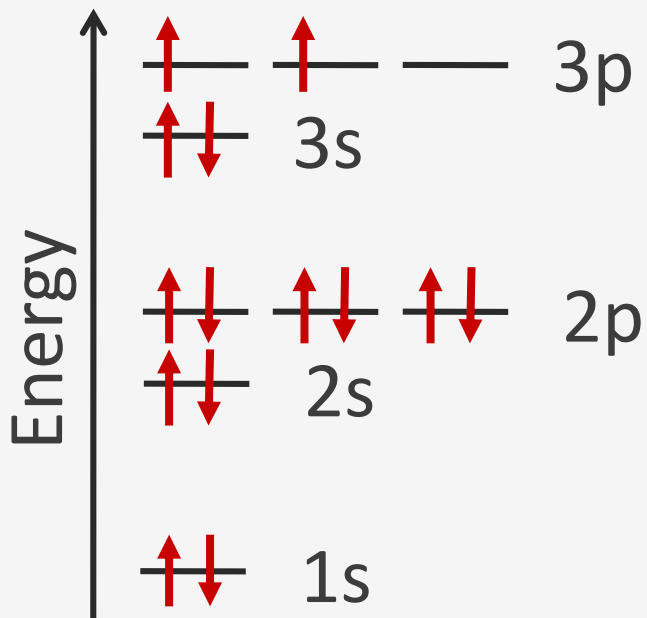
Periodic Table of the Elements

- hydrogen
- alkali metals
- alkali earth metals
- transition metals
- hydrogen
- alkali metals
- alkali earth metals
- transition metals

					2 He
5 B	6 C	7 N	8 O	9 F	10 Ne
13 Al					



How strong are electrons bonded: **the Si atom**



1 H	
3 Li	4 Be
11 Na	12 Mg

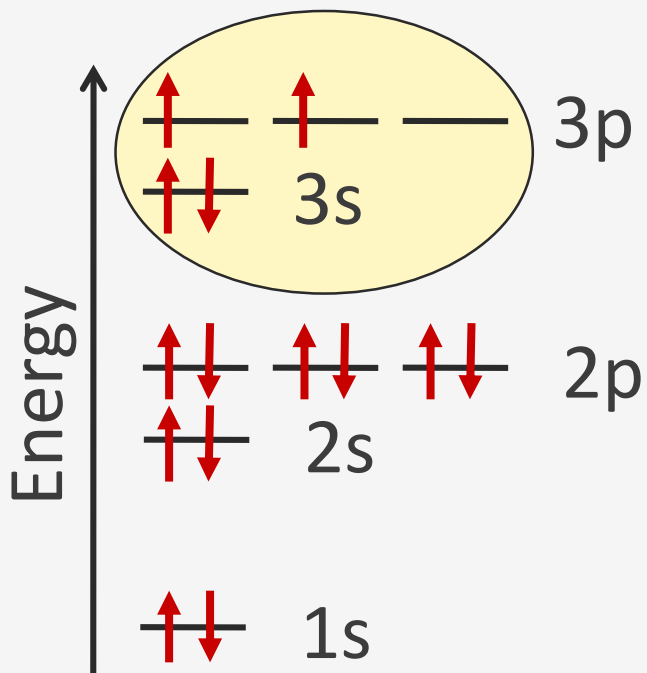
Periodic Table of the Elements

hydrogen	hydrogen
alkali metals	alkali metals
alkali earth metals	alkali earth metals
transition metals	transition metals

					2 He
5 B	6 C	7 N	8 O	9 F	10 Ne
13 Al	14 Si				



Bonding of electrons in Si network



							VIIIA
							2 He 4.0026
		IIIA	IVA	VA	VIA	VIIA	
		5 B 10.811	6 C 12.011	7 N 14.007	8 O 15.999	9 F 18.998	10 Ne 20.180
		13 Al 26.982	14 Si 28.086	15 P 30.974	16 S 32.065	17 Cl 35.453	18 Ar 39.948
IB	IIB						
29 Cu 63.546	30 Zn 65.38	31 Ga 69.723	32 Ge 72.64	33 As 74.922	34 Se 78.96	35 Br 79.904	36 Kr 83.798
47 Ag 107.87	48 Cd 112.41	49 In 114.82	50 Sn 118.71	51 Sb 121.76	52 Te 127.60	53 I 126.90	54 Xe 131.29
79 Au 196.97	80 Hg 200.59	81 Tl 204.38	82 Pb 207.2	83 Bi 208.98	84 Po [209]	85 At [210]	86 Rn [222]

Si atom: 14 electrons

Bonding of electrons in Si network

