

EE113FZ

Solid State Electronics

Lecture 2: Atoms & The Periodic Table

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What is to be discussed today?

- Terminology used in describing matter.
- What is an atom and what is in it.
- Introduction to the periodic table of elements.
- How atoms interact.
- Beyond simple atoms (complications due to charge, mass, and bonding structures).
- Different types of molecular arrangements.

Key Terms

- **Atoms** – the smallest part of an element that can react.
- **Element** – a substance made entirely from one type of atom. There are ~118 elements currently.
- **Molecule** – the smallest part of an element or compound that can exist and still retain the properties of that element or compound.
- **Mixture** – made of 2 or more substances each of which maintains its identity and can **be separated**.
- **Compound** – made of 2 or more substances and the properties of the substance are different and **can not be separated**.

What is an Atom?

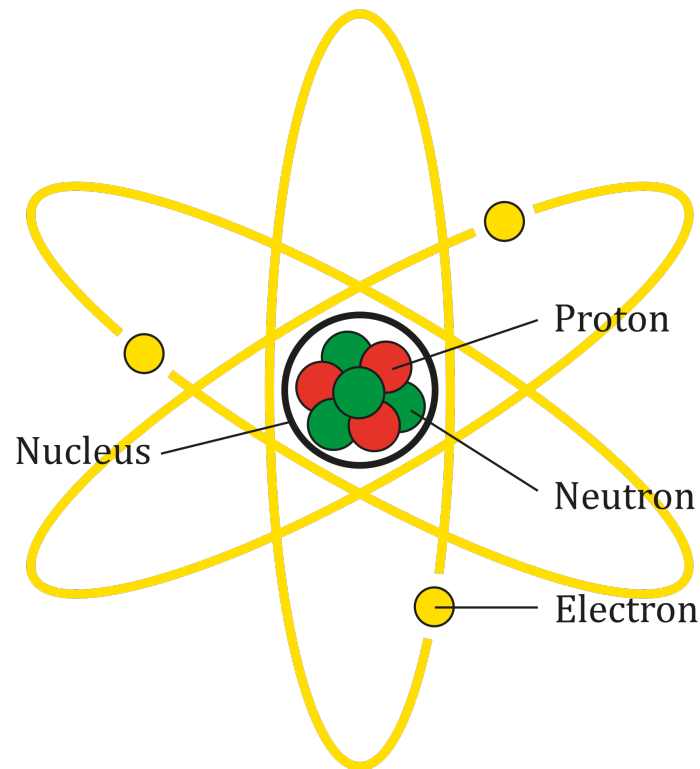
- **Atoms are the building blocks** of everything.
- Combinations of atoms create all that is known as matter.
- Atoms are made up by 3 subatomic particles:
 - **Neutrons** – no charge and a large mass, found in the centre of an atom.
 - **Protons** – a positive charge and a large mass, found in the centre of an atom.
 - **Electrons** – a negative charge with small mass, found outside the centre of an atom.

What is an Atom?

- As electronic engineers, we are only interested in **electrons and protons!**
- Both protons and neutrons are composite subatomic particles. They are made of elementary subatomic particles, e.g., quarks. But this is all too complicated for electronic engineers.
- Also antimatter is the same as matter but with an opposite charge 😊. It is unfortunately not very stable (one can generate them on particle accelerators but it is not of much use to electronic engineers, at least for now).

What Does an Atom Look Like?

- Might look something like the figure below, with the protons and neutrons closely packed together in a core with the electrons traveling in orbits around the core.



Summary: What is an Atom?

Component	Charge	Mass	Location
Neutron	None	Large	Centre
Proton	Positive (+)	Large	Centre
Electron	Negative (-)	Very small	Outside

The Periodic Table of Elements

- There are many different types of elements.
- They are listed and arranged in what is called the periodic table of elements.
- They are listed by the number of protons (**atomic number**, a term you will learn in a few minutes) in the atoms of each element, from lowest to highest.
- They are also listed by how fast (how aggressively) they react to other elements.

Periodic Table of the Elements

Group		Periodic Table of the Elements																18														
1																		0														
1a																																
Period	1	2											13	14	15	16	17	18														
1	1 H Hydrogen 1s ¹	2 He Helium 1s ²											5 B Boron 1s ² 2s ² 2p ¹	6 C Carbon 1s ² 2s ² 2p ²	7 N Nitrogen 1s ² 2s ² 2p ³	8 O Oxygen 1s ² 2s ² 2p ⁴	9 F Fluorine 1s ² 2s ² 2p ⁵	10 Ne Neon 1s ² 2s ² 2p ⁶														
2	3 Li Lithium 1s ² 2s ¹	4 Be Beryllium 1s ² 2s ²											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														
3	11 Na Sodium [Ne]3s ¹	12 Mg Magnesium [Ne]3s ²	3 IIIb	4 IVb	5 Vb	6 VIb	7 VIIb	8 VIIIb	9 VIIIb	10 VIIIb	11 Ib	12 IIb	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														
4	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														
5	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														
6	55 Cs Cesium [Xe]6s ¹	56 Ba Barium [Xe]6s ²	57 La Lanthanum [Xe]5d ¹ 6s ²	58 Ce Cerium [Xe]4f ¹ 5d ¹ 6s ²	59 Pr Praseodymium [Xe]4f ³ 6s ²	60 Nd Neodymium [Xe]4f ⁴ 6s ²	61 Pm Promethium [Xe]4f ⁵ 6s ²	62 Sm Samarium [Xe]4f ⁶ 6s ²	63 Eu Europium [Xe]4f ⁷ 6s ²	64 Gd Gadolinium [Xe]4f ⁷ 5d ¹ 6s ²	65 Tb Terbium [Xe]4f ⁹ 6s ²	66 Dy Dysprosium [Xe]4f ¹⁰ 6s ²	67 Ho Holmium [Xe]4f ¹¹ 6s ²	68 Er Erbium [Xe]4f ¹² 6s ²	69 Tm Thulium [Xe]4f ¹³ 6s ²	70 Yb Ytterbium [Xe]4f ¹⁴ 6s ²	71 Lu Lutetium [Xe]4f ¹⁴ 5d ¹ 6s ²	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
7	87 Fr Francium [Rn]7s ¹	88 Ra Radium [Rn]7s ²	89 Ac Actinium [Rn]5f ¹ 6d ¹ 7s ²	90 Th Thorium [Rn]5f ¹ 6d ² 7s ²	91 Pa Protactinium [Rn]5f ² 6d ¹ 7s ²	92 U Uranium [Rn]5f ³ 6d ¹ 7s ²	93 Np Neptunium [Rn]5f ⁴ 6d ¹ 7s ²	94 Pu Plutonium [Rn]5f ⁶ 7s ²	95 Am Americium [Rn]5f ⁷ 7s ²	96 Cm Curium [Rn]5f ⁷ 6d ¹ 7s ²	97 Bk Berkelium [Rn]5f ⁹ 7s ²	98 Cf Californium [Rn]5f ¹⁰ 7s ²	99 Es Einsteinium [Rn]5f ¹¹ 7s ²	100 Fm Fermium [Rn]5f ¹² 7s ²	101 Md Mendelevium [Rn]5f ¹³ 7s ²	102 No Nobelium [Rn]5f ¹⁴ 7s ²	103 Lr Lawrencium [Rn]5f ¹⁴ 6d ¹ 7s ²	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 ⁹ 7s ¹	111 Rg Roentgenium [Rn]5f ¹⁴ 6d ¹⁰ 7s ¹	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

Alkali Metals	Lanthanide Series
Alkaline Earth Metals	Actinide Series
Transition Metals	Halogens
Non-metals	Inert Gases
Other Metals	

Atomic Number	1	1.01
Atomic Weight*		
Symbol	H	
Name	Hydrogen	
Electron Configuration**	1s ¹	

Aa -Solid

Aa -Gas

Aa -Liquid

Aa -Synthetically Prepared

* Based on Carbon-12. (###) represents most stable or most stable expected isotope.

** Some electron configurations are based on theoretical expected arrangements.

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Table arranged from the least number of protons, H for hydrogen with only a single proton, to the most number of protons.

Periodic Table of the Elements

Group 1 1a 2 2a 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18

1 1.01 H Hydrogen 2 4.00 He Helium

3 6.94 Li Lithium 4 9.01 Be Beryllium

5 10.81 B Boron 6 12.01 C Carbon 7 14.01 N Nitrogen 8 16.00 O Oxygen 9 19.00 F Fluorine 10 20.18 Ne Neon

11 22.99 Na Sodium 12 24.31 Mg Magnesium

13 26.98 Al Aluminum 14 28.09 Si Silicon 15 30.97 P Phosphorus 16 32.07 S Sulfur 17 35.45 Cl Chlorine 18 39.95 Ar Argon

19 39.10 K Potassium 20 40.08 Ca Calcium 21 44.96 Sc Scandium 22 47.87 Ti Titanium 23 50.94 V Vanadium 24 52.00 Cr Chromium 25 54.94 Mn Manganese 26 55.85 Fe Iron 27 58.93 Co Cobalt 28 58.69 Ni Nickel 29 63.55 Cu Copper 30 65.39 Zn Zinc 31 69.72 Ga Gallium 32 72.61 Ge Germanium 33 74.92 As Arsenic 34 78.96 Se Selenium 35 79.90 Br Bromine 36 83.80 Kr Krypton

37 85.47 Rb Rubidium 38 87.62 Sr Strontium 39 88.91 Y Yttrium 40 91.22 Zr Zirconium 41 92.91 Nb Niobium 42 95.94 Mo Molybdenum 43 (98) Tc Technetium 44 101.07 Ru Ruthenium 45 102.91 Rh Rhodium 46 106.42 Pd Palladium 47 107.87 Ag Silver 48 112.41 Cd Cadmium 49 114.82 In Indium 50 118.71 Sn Tin 51 121.76 Sb Antimony 52 127.60 Te Tellurium 53 126.90 I Iodine 54 131.29 Xe Xenon

55 132.91 Cs Cesium 56 137.33 Ba Barium 57 (138) La Lanthanum 58 (140) Ce Cerium 59 (140.91) Pr Praseodymium 60 (144.24) Nd Neodymium 61 (145) Pm Promethium 62 150.36 Sm Samarium 63 151.96 Eu Europium 64 157.25 Gd Gadolinium 65 158.93 Tb Terbium 66 162.50 Dy Dysprosium 67 164.93 Ho Holmium 68 167.26 Er Erbium 69 168.93 Tm Thulium 70 173.04 Yb Ytterbium 71 174.97 Lu Lutetium

87 (223) Fr Francium 88 (226) Ra Radium 89 (227) Ac Actinium 90 (232.04) Th Thorium 91 (231.04) Pa Protactinium 92 (238.03) U Uranium 93 (237) Np Neptunium 94 (244) Pu Plutonium 95 (243) Am Americium 96 (247) Cm Curium 97 (247) Bk Berkelium 98 (251) Cf Californium 99 (252) Es Einsteinium 100 (257) Fm Fermium 101 (258) Md Mendelevium 102 (259) No Nobelium 103 (262) Lr Lawrencium

104 (261) Rf Rutherfordium 105 (268) Db Dubnium 106 (271) Sg Seaborgium 107 (270) Bh Bohrium 108 (277) Hs Hassium 109 (276) Mt Meitnerium 110 (281) Ds Darmstadtium 111 (280) Rg Roentgenium 112 (285) Cn Copernicium 113 (284) Uut Ununtrium 114 (289) Fl Flerovium 115 (288) Uup Ununpentium 116 (293) Lv Livermorium 117 (294) Uus Ununseptium 118 (294) Uuo Ununoctium

Legend:

- Alkali Metals (Orange)
- Alkaline Earth Metals (Yellow)
- Transition Metals (Green)
- Non-metals (Light Blue)
- Other Metals (Dark Blue)
- Lanthanide Series (Purple)
- Actinide Series (Pink)
- Halogens (Light Green)
- Inert Gases (Light Orange)

Properties:

- Aa - Solid
- Aa - Gas
- Aa - Liquid
- Aa - Synthetic
- Pre - Predicted

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Listed in columns – most reactive on the left to least reactive on the right.

All the elements in Group 1 are very reactive!

The further down the column the more vigorous the reaction!



Periodic Table of the Elements

Group 1

1a

Period

1 H 1.01

2 Li 6.94 Be 9.01

3 Na 22.99 Mg 24.31

4 K 39.10 Ca 40.08 Sc 44.96 Ti 47.87 V 50.94 Cr 52.00 Mn 54.94 Fe 55.85 Co 58.93 Ni 58.69 Cu 63.55 Zn 65.38 Ga 69.72 Ge 72.61 As 74.92 Se 78.96 Br 79.90 Kr 83.80

5 Rb 85.47 Sr 87.62 Y 88.91 Zr 91.22 Nb 92.91 Mo 95.94 Tc 98 (98) Ru 101.07 Rh 104.91 Pd 106.42 Ag 107.87 Cd 112.41 In 114.82 Sn 118.71 Sb 121.76 Te 127.60 I 126.90 Xe 131.29

6 Cs 132.91 Ba 137.33 ♦ 72 178.49 Hf 178.49 Ta 180.95 W 183.84 Re 186.21 Os 190.23 Ir 192.22 Pt 195.08 Au 196.97 Hg 200.59 Tl 204.38 Pb 207.2 Bi 208.98 Po (209) At (210) Rn (222)

7 Fr 223 Ra (226) ★ 104 (261) Rf 105 (265) Db 106 (271) Sg 107 (279) Bh 108 (277) Hs 109 (279) Mt 110 (281) Ds 111 (281) Rg 112 (285) Cn 113 (284) Uut 114 (289) Fl 115 (288) Uup 116 (293) Lv 117 (294) Uus 118 (294) Uuo

Group 2

2a

Period

1 He 4.00

2 Ne 20.18

3 Ar 39.95

4 Kr 83.80

5 Xe 131.29

6 Rn (222)

Legend:

- Alkali Metals
- Alkaline Earth Metals
- Transition Metals
- Non-metals
- Lanthanide Series
- Actinide Series
- Halogens
- Inert Gases
- Other Metals

Hydrogen (H) Example:

Atomic Number: 1, Atomic Weight: 1.01, Symbol: H, Name: Hydrogen, Electron Configuration: 1s¹

Physical States:

- Aa** - Solid
- Aa** - Gas
- Aa** - Liquid
- Aa** - Synthetically Prepared

* Based on Carbon-12. (##) represents most stable or most stable expected isotope.
 ** Some electron configurations are based on theoretical expected arrangements.
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Also known as alkaline metals.

Almost empty outer electron shells.

Less dense than water (floats), low ionisation energy.

<https://www.youtube.com/watch?v=QQF61CFOySw>

Gives you an idea of the reaction rate. Do not try any of this unless you are in a lab!

Periodic Table of the Elements

Group 1
1a

Period 1

Alkali Metals

Alkaline Earth Metals

Transition Metals

Non-metals

Lanthanide Series

Actinide Series

Halogens

Inert Gases

Other Metals

Atomic Number

Atomic Weight

Symbol

Name

Electron Configuration

										13	14	15	16	17	18
										IIIA	IVA	VA	VIA	VIIA	0
										5	6	7	8	9	10
										B	C	N	O	F	Ne
										Boron	Carbon	Nitrogen	Oxygen	Fluorine	Neon
										13	14	15	16	17	18
										Al	Si	P	S	Cl	Ar
										Aluminum	Silicon	Phosphorus	Sulfur	Chlorine	Argon
										19	20	21	22	23	24
										K	Ca	Sc	Ti	V	Cr
										Potassium	Calcium	Scandium	Titanium	Vanadium	Chromium
										37	38	39	40	41	42
										Rb	Sr	Y	Zr	Nb	Mo
										Rubidium	Strontium	Yttrium	Zirconium	Niobium	Molybdenum
										55	56	57	58	59	60
										Cs	Ba	La	Ce	Pr	Nd
										Cesium	Barium	Lanthanum	Cerium	Praseodymium	Neodymium
										87	88	89	90	91	92
										Fr	Ra	Ac	Th	Pa	U
										Francium	Radium	Actinium	Thorium	Protactinium	Uranium

Aa - Solid
Aa - Gas
Aa - Liquid
Aa - Synthetically Prepared

* Based on Carbon-12. (###) represents most stable or most stable expected isotope.
 ** Some electron configurations are based on theoretical expected arrangements.
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Group 18 are the noble gases.

Not reactive unless exposed to an electric field. They have pretty colours.

Full outer electron shell.



We will be most interested in columns 13, 14 and 15 but more on that later.

Periodic Table of the Elements

Group

1
1a

Period

1

2

3

4

5

6

7

Alkali Metals

Alkaline Earth Metals

Transition Metals

Non-metals

Other Metals

Lanthanide Series

Actinide Series

Halogens

Inert Gases

Atomic Number

1

Name

Hydrogen

Electron Configuration**

Atomic Weight*

1.01

Symbol

H

13		14		15		16		17		18	
IIla		IVa		Va		VIa		VIIa		0	
5	B	6	C	7	N	8	O	9	F	10	Ne
13	Al	14	Si	15	P	16	S	17	Cl	18	Ar
31	Ga	32	Ge	33	As	34	Se	35	Br	36	Kr
49	In	50	Sn	51	Sb	52	Te	53	I	54	Xe
81	Tl	82	Pb	83	Bi	84	Po	85	At	86	Rn
113	Nh	114	Fl	115	Mc	116	Lv	117	Uus	118	Uuo

Aa - Solid

Aa - Gas

Aa - Liquid

Aa - Synthetically Prepared

57		58		59		60		61		62		63		64		65		66		67		68		69		70		71	
La		Ce		Pr		Nd		Pm		Sm		Eu		Gd		Tb		Dy		Ho		Er		Tm		Yb		Lu	
89	Ac	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

* Based on Carbon-12. (###) represents most stable or most stable expected isotope.

** Some electron configurations are based on theoretical expected arrangements.

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The outermost electron shell fills up as we move from the left to the right.

Periodic Table of the Elements

	Group 1																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																	
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How Do Atoms Function?

- Atoms function by interacting with other atoms around them.
- Three main ways to do this:
 - Bonding – of which there are various types;
 - Crystal formation – starts with bonding but then continues to grow;
 - Fusion – where the nuclei of atoms combine making a bigger atom!
- To understand how these processes happen we need to look at the various quantities that describe an atom.

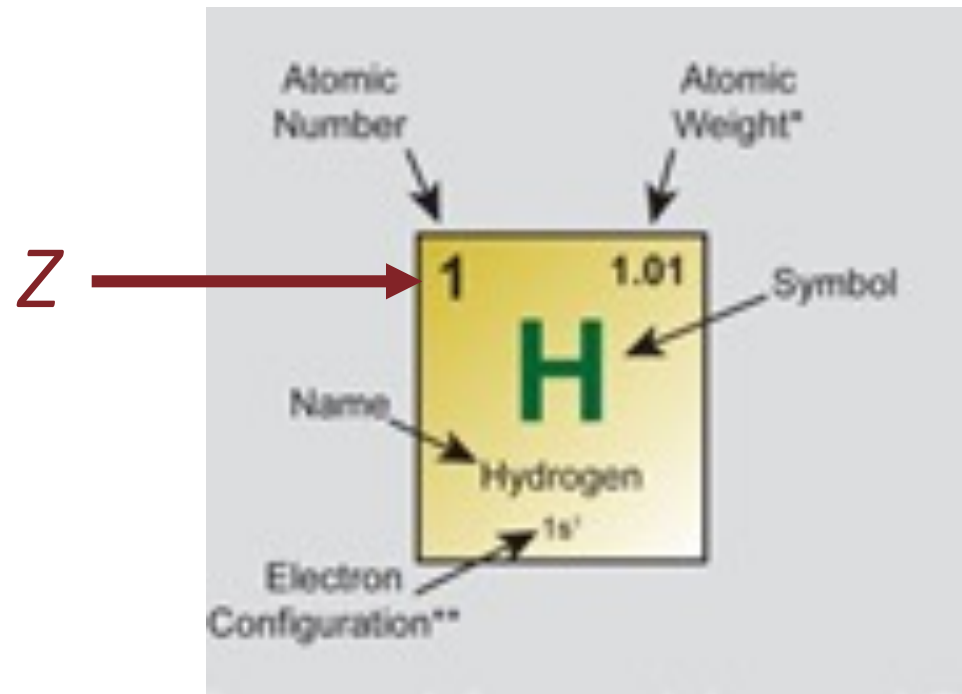
Numbers Associated with an Atom

- There is a lot of information about an atom based on numbers provided in the periodic table.
- These include:
 - Number of protons;
 - Number of neutrons;
 - Number of electrons;
 - Atomic weight;
 - How the electrons are arranged.
- They have their own symbols and we need a little math to get all the answers.

The diagram shows a single element box from the periodic table for Hydrogen. The box is yellow with a black border. It contains the following information: the atomic number '1' in the top left, the atomic weight '1.01' in the top right, the chemical symbol 'H' in the center, the name 'Hydrogen' at the bottom, and the electron configuration '1s¹' at the very bottom. Arrows point from labels outside the box to each of these five pieces of information.

Atomic Number	Atomic Weight*	Symbol	Name	Electron Configuration**
1	1.01	H	Hydrogen	1s ¹

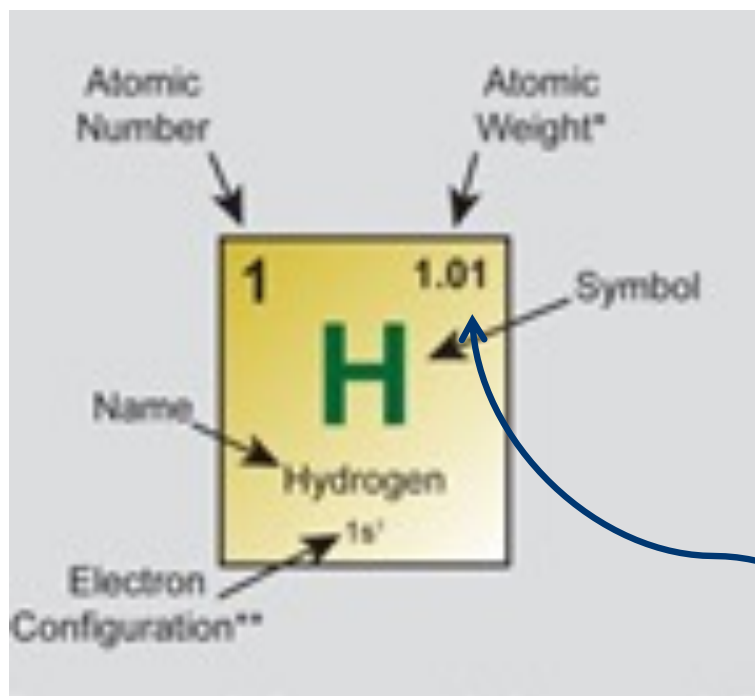
Atomic Number



The atomic number is the number of protons in that atom (top left side).

This is also known by the symbol, Z.

Atomic Weight



The diagram shows a single element box from the periodic table for Hydrogen. The box is yellow with a black border. It contains the following information: the atomic number '1' in the top left, the atomic weight '1.01' in the top right, the symbol 'H' in the center, the name 'Hydrogen' below the symbol, and the electron configuration '1s¹' at the bottom. Labels with arrows point to each of these features: 'Atomic Number' points to '1', 'Atomic Weight*' points to '1.01', 'Symbol' points to 'H', 'Name' points to 'Hydrogen', and 'Electron Configuration**' points to '1s¹'. A blue curved arrow originates from the 'Symbol' label and points towards the text below the table.

Atomic Number	Atomic Weight*
1	1.01
H	
Hydrogen	
1s¹	

The atomic weight gives information about the number of neutrons.

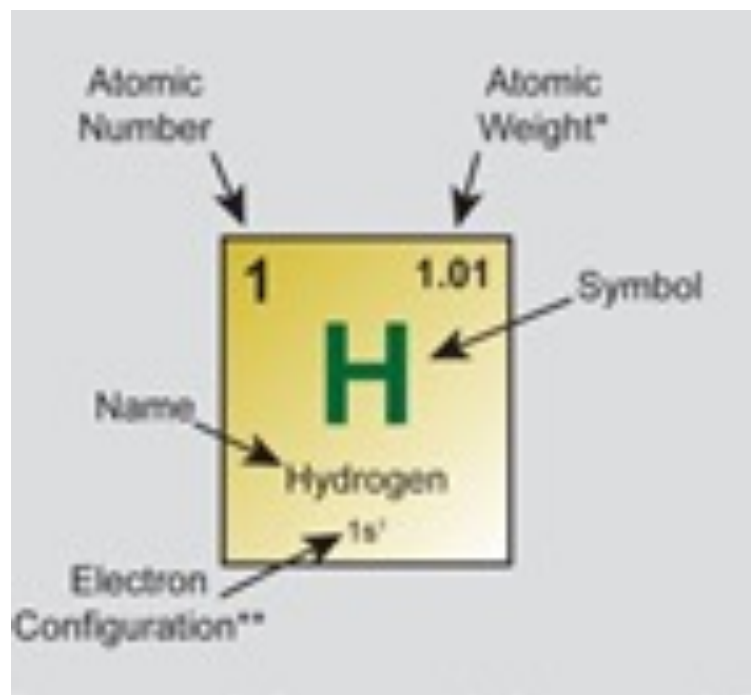
The number of neutrons = (rounded atomic weight) – (atomic number).

The number of neutrons = $A - Z$ (some complication here but we will see it later).

The atomic weight is also known by the symbol, A .

Number of Electrons

What about electrons?



The diagram shows a single element tile from the periodic table for Hydrogen. The tile is yellow with a black border. It contains the following information: the atomic number '1' in the top left, the atomic weight '1.01' in the top right, the chemical symbol 'H' in the center, the name 'Hydrogen' below the symbol, and the electron configuration '1s¹' at the bottom. Arrows point from labels outside the tile to these specific pieces of information: 'Atomic Number' points to '1', 'Atomic Weight*' points to '1.01', 'Symbol' points to 'H', 'Name' points to 'Hydrogen', and 'Electron Configuration**' points to '1s¹'.

Atomic Number	1	Atomic Weight*	1.01
		Symbol	H
Name		Hydrogen	
Electron Configuration**		1s¹	

The number of electrons = the number of protons – why?

As the overall charge on an atom is neutral, so they have to be equal.

Remember that protons have positive charges and electrons have negative charges.

It can also be found under the electron configuration number in the bottom centre.

Example: Numbers for Hydrogen (H)

So let's do an easy example – take hydrogen, the first element in the periodic table.

Atomic number, $Z = 1$.

No. of protons = atomic number = 1.

No. of electrons = no. of protons = 1.

No. of neutrons =
(atomic weight, A) rounded – (atomic number, Z).

Atomic weight, A , = 1.01, round this to 1.

No. of neutrons = $1 - 1 = 0$.

The diagram shows a single element box for Hydrogen (H) from the periodic table. The box is yellow with a black border. It contains the following information: the atomic number '1' in the top left, the atomic weight '1.01' in the top right, the symbol 'H' in the center, the name 'Hydrogen' at the bottom, and the electron configuration '1s¹' at the very bottom. Arrows point from external labels to these specific parts of the box: 'Atomic Number' points to '1', 'Atomic Weight*' points to '1.01', 'Symbol' points to 'H', 'Name' points to 'Hydrogen', and 'Electron Configuration**' points to '1s¹'.

Atomic Number	1	Atomic Weight*	1.01
Name		Symbol	
Hydrogen		H	
Electron Configuration**		1s¹	

Example: Numbers for Silicon (Si)

So let's do another easy example – take silicon (Si), the 14th element in the periodic table.

Atomic number, $Z = 14$.

No. of protons = atomic number = 14.

No. of electrons = no. of protons = 14.

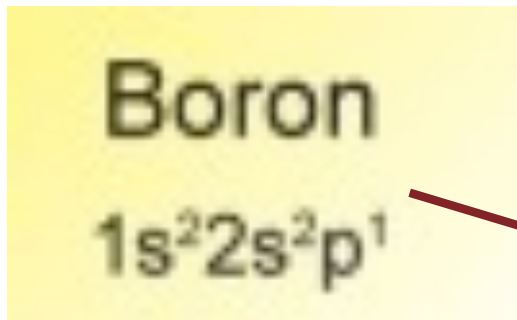
No. of neutrons =
(atomic weight, A) rounded – (atomic number, Z).

Atomic weight, $A = 28.09$, round it to 28.

No. of neutrons = $28 - 14 = 14$.

13 IIla	14 IVa	15 Va
5 10.81 B Boron $1s^2 2s^2 p^1$	6 12.01 C Carbon $1s^2 2s^2 p^2$	7 14.01 N Nitrogen $1s^2 2s^2 p^3$
13 26.98 Al Aluminum $[\text{Ne}] 3s^2 p^1$	14 28.09 Si Silicon $[\text{Ne}] 3s^2 p^2$	15 30.97 P Phosphorus $[\text{Ne}] 3s^2 p^3$
31 69.72 Ga Gallium $[\text{Ar}] 3d^{10} 4s^2 p^1$	32 72.61 Ge Germanium $[\text{Ar}] 3d^{10} 4s^2 p^2$	33 74.92 As Arsenic $[\text{Ar}] 3d^{10} 4s^2 p^3$

Electron Configuration



This is the electron configuration.
More on this important aspect later!

13 IIla	14 IVa	15 Va
5 10.81 B Boron $1s^2 2s^2 p^1$	6 12.01 C Carbon $1s^2 2s^2 p^2$	7 14.01 N Nitrogen $1s^2 2s^2 p^3$
13 26.98 Al Aluminum [Ne] $3s^2 p^1$	14 28.09 Si Silicon [Ne] $3s^2 p^2$	15 30.97 P Phosphorus [Ne] $3s^2 p^3$
31 69.72 Ga Gallium [Ar] $3d^{10} 4s^2 p^1$	32 72.61 Ge Germanium [Ar] $3d^{10} 4s^2 p^2$	33 74.92 As Arsenic [Ar] $3d^{10} 4s^2 p^3$

When Things Break Down

So let's do another example – take nickel (Ni), the 28th element in the periodic table.

Atomic number, $Z = 28$.

No. of protons = atomic number = 28.

No. of electrons = no. of protons = 28.

No. of neutrons =
(atomic weight, A) rounded – (atomic number, Z).

A periodic table entry for Nickel (Ni) on a light green background. The entry is a square containing the following information: the atomic number '28' in the top left corner, the atomic weight '58.69' in the top right corner, the element symbol 'Ni' in large bold letters in the center, the element name 'Nickel' in smaller letters below the symbol, and the electron configuration '[Ar]3d⁸4s²' at the bottom.

28	58.69
Ni	
Nickel	
[Ar]3d ⁸ 4s ²	

Atomic weight, $A = 58.69$, shall we round it up to 59 or round it down to 58?

No. of neutrons = $59 - 28 = 31$ or $58 - 28 = 30$, which one is correct?

When Things Break Down

So let's do another example – take nickel (Ni), the 28th element in the periodic table.

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No. of protons = atomic number = 28.

No. of electrons = no. of protons = 28.

No. of neutrons =
(atomic weight, A) rounded – (atomic number, Z).

A periodic table entry for Nickel (Ni). The entry is a light green square. In the top left corner is the atomic number '28'. In the top right corner is the atomic weight '58.69'. In the center is the element symbol 'Ni' in large, bold, black letters. Below the symbol is the element name 'Nickel' in smaller black letters. At the bottom is the electron configuration '[Ar]3d⁸4s²' in even smaller black letters.

28	58.69
Ni	
Nickel	
[Ar]3d ⁸ 4s ²	

Atomic weight, $A = 58.69$, shall we round it up to 59 or round it down to 58?

No. of neutrons = $59 - 28 = 31$ or $58 - 28 = 30$, which one is correct?

Well, the answer is, they can both be correct.

If you feel that this is not confusing enough, there are some other numbers, ranging from 20 to 50 that can all be correct!

Beyond Simple Atoms

- The nature is unfortunately not as simple as what we just discussed.
- There are at least three factors that complicate things:
 - Charge;
 - Mass;
 - Bonding structure.

Charge: Ion & Cation

- Atoms are neutrally charged overall (the number of protons = number of electrons);
- Give it an extra charge, of any type, and it now becomes an **ion**;
- If an atom has an extra positive charge (it usually happens when it lost an electron), it will be represented by a “+” symbol, for example, H^+ ;
- A positively charged ion is also called a **cation**.

Charge: Ion & Anion

- Similarly if an atom receives an extra electron, it becomes a negatively charged ion;
- It will be represented by the “-” symbol, for example, O^- ;
- In the case of 2 extra electrons, it will be noted as O^{2-} ;
- A negatively charged ion is also called an **anion**.

Mass: Isotopes

- The atomic mass of atoms can be different even if they retain the same atomic number;
- This means that the number of neutrons is different but the number of protons is the same;
- One of the most common example is carbon (C), where its atomic mass can be 12, 13 or 14 daltons (1 dalton \approx the mass of a proton or the mass of a neutron);
- They are referred to as carbon-12, carbon-13 and carbon-14 (carbon-12 is the most common one);
- Variations of mass of the same element are called **Isotopes**. It has no effect on the chemical properties of atoms.
- Isotopes are widely used in archaeology (radiocarbon dating uses carbon-14), medicine (gamma rays and deuterium metabolic imaging), and food processing.

Mass: Isotopes

- Now you will ask which isotope's "atomic weight" we are really referring to in the periodic table.
- The answer is "all of them" and at the same time "none of them".
- Standard atomic weight (what we find in the periodic table) of a chemical element is the **weighted arithmetic mean** of the relative isotopic masses of all isotopes of that element **weighted by each isotope's abundance on Earth**.

Bonding Structure: Allotropes

- The same element can have different physical appearances.
- This is due to different bonding arrangements that can occur (when atoms gather together to form solids).
- They are called **allotropes** and the best known is carbon:
 - Graphite – a sheet of hexagonal lattice, very slippery;
 - Diamond – a tetrahedral lattice, very, very strong.

Common Molecular Arrangements

- We will deal with this topic in more detail a little later on.
- Three main types of molecular arrangements:
 - **Linear**, where the bond angle is **180°** ;
 - **Trigonal**, where the bond angle is **120°** ;
 - **Tetrahedral**, where the bond angle is **109.5°** .
- The size of these angles has to do with valence shells and electron pairs. More on this later.

Common Molecular Arrangements

Configuration	Bonding Partners	Bond Angles	Example
Tetrahedral	4	109.5°	
Trigonal	3	120°	
Linear	2	180°	