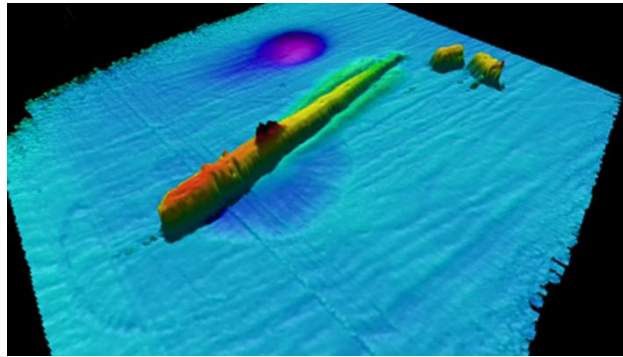
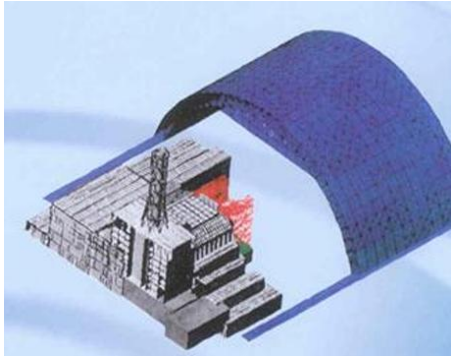
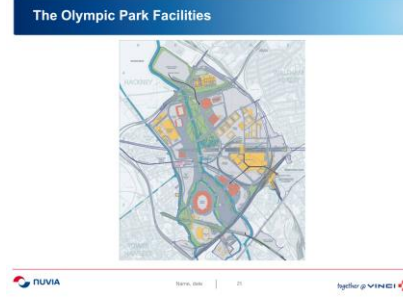
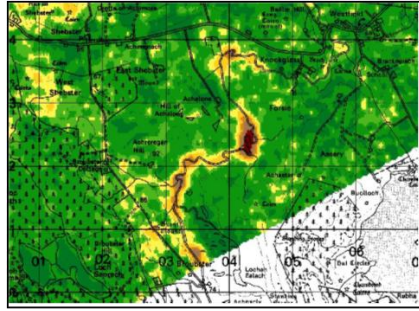


Me

- Manchester – Cambridge – Harwell post grad
- Coal Board Research Labs
- UKAEA – AEAT – NUKEM – ADVENT – NUVIA
- Research Scientist – Analytical Laboratory Manager
- Consultant – Research Manager



Talks



Pure gold - honest



Local U3As speaker sharing

COVID made quite a few of the 'Thames Valley' U3As turn to zoom – and we contacted each other and shared on-line speakers. We did the same for Café Sci

After COVID we gradually moved away from zoom, but people from local groups exchanged their speakers.

More recently Peter Carson from Abingdon (they were not members of the original COVID U3As) has taken to contacting wider afield.

Thus my presence here today – and the reciprocal talk that Paul is giving at Didcot.

I've already been doing exchange talks for five or so years – and this year's contribution was on Rare Earths. I have lots of others.

Didcot Café Scientifique

Tuesday 17th March 2026

Andrew Kaye – Flying High with atmospheric science

Tuesday 21st April 2026

Janet High – Title tbc

Tuesday 19th May 2026

Victoria Robinson – Dinosaurs

Tuesday 16th June 2026

Jane Sellwood – Water: How we use it and abuse it

Tuesday 21st July 2026 – TBC

Summer break

Tuesday 15th September 2026 - TBC

Tuesday 20th October 2026

Adrian Mancuso – Director of Physical Science at Diamond Light Source

Auditorium

Tuesday 17th November 2026

John Broadbent – Honey Bees

Didcot U3A talks – 2026

11am – First Tuesday of the month - King Alfred's Hall

All welcome – usually £1 per head for hall rental – and if you like this then.....

3rd - March – Julian – Google AI

7th April – Paul Le Blond – South Bucks – Frank Whittle and the Jet Engine

5th May – Richard Bull – Sunset – Sunrise – the Equation of Time

2nd June - Janet High – NHS screening – should more cancers be included?

I do of course need to offer you some of my terrible jokes and puns as a warm-up

Jonesy



“So, how much is all this tranquility worth to you?”



AMERICAN HISTORY:
AN ALTERNATIVE
READING

*"I claim this
country in the
name of
Greenland"*

- PILBROW -



be M.D.





**Once again it's a busy time at the
Henge....
Moving the stones back one hour**





Dad, can you explain to me what a solar eclipse is?

No sun

@artmemescentral

Tonight, we remember Konrad Adenauer who invented and gave his name to British Summer Time.



HEATWAVES CAUSE CONFUSION IN THE ELDERLY



There's
no such thing
as global
warming

The Atomic Structure of the Rare Earth Elements

Originally produced because my group asked me why they were...

Special !

The Summer Students

For many years I was the company(s) organiser for summer students.



‘We’ can’t recruit people with any experience!

Comment – just how many private health companies have paid to educate their staff – or have they pilfered them from the NHS?

The Summer Students

I used to try and find interesting research for these students – but as a fall back I always set them a research project they could work on.

I suppose for something like 20 years one of these projects was rare earth metals.

In fact, I often had more than one student per year – so most years one of them did rare earths.

Many of these kids were really bright (some so bright I would not recruit them) so I gained some good insight into the issues

The Science

Over the years the individual elements were identified

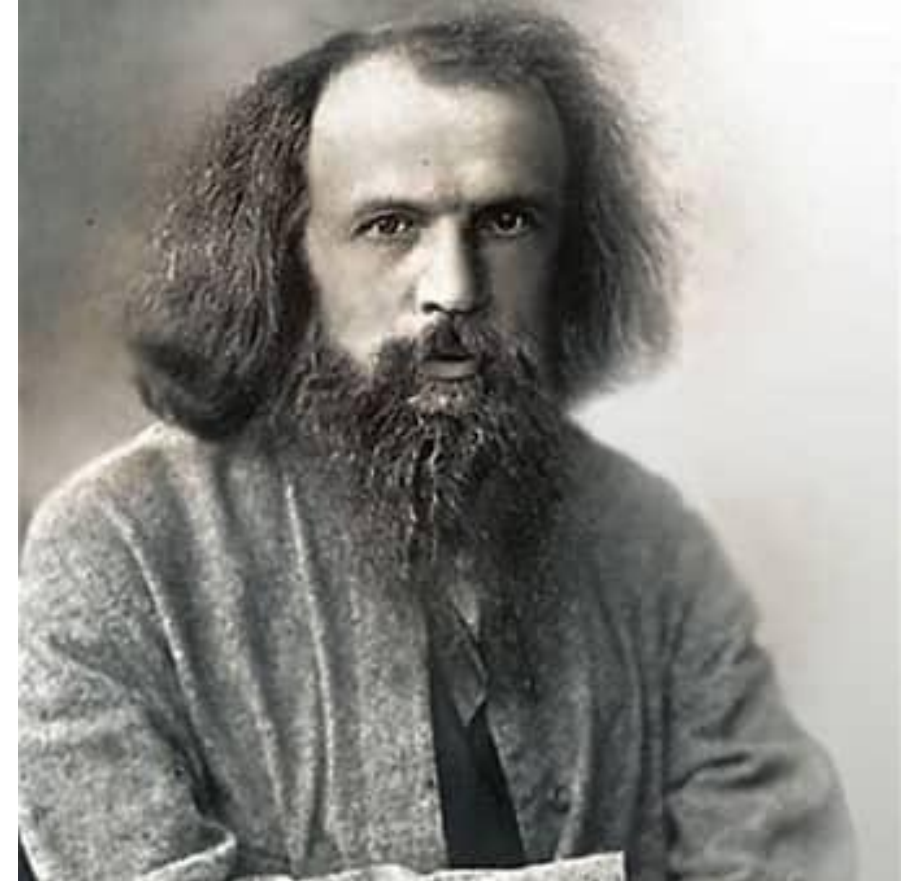
An element can be essentially defined as an atom with a nucleus that contain a specific number of protons – and thus the same number of atomic electrons

Hydrogen 1, Helium 2, Iron 26 etc

These were eventually put in some sort of order by Mendeleev with 'the periodic table'.

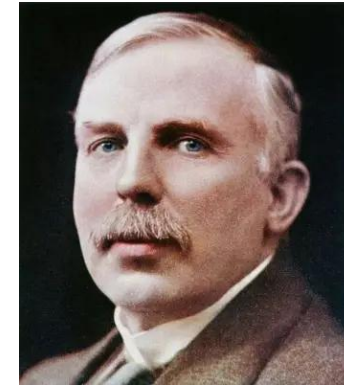
I H 1.01	II	III	IV	V	VI	VII	VIII		
Li 6.94	Be 9.01	B 10.8	C 12.0	N 14.0	O 16.0	F 19.0			
Na 23.0	Mg 24.3	Al 27.0	Si 28.1	P 31.0	S 32.1	Cl 35.5			
K 39.1	Ca 40.1		Ti 47.9	V 50.9	Cr 52.0	Mn 54.9	Fe 55.9	Co 58.9	Ni 58.7
Cu 63.5	Zn 65.4			As 74.9	Se 79.0	Br 79.9			
Rb 85.5	Sr 87.5	Y 88.9	Zr 91.2	Nb 92.9	Mo 95.9		Ru 101	Rh 103	Pd 106
Ag 108	Cd 112	In 115	Sn 119	Sb 112	Te 128	I 127			
Cs 133	Ba 137	La 139		Ta 181	W 184		Os 194	Ir 192	Pt 195
Au 197	Hg 201	Tl 204	Pb 207	Bi 209					
			Th 232			U 238			

Mendeleev's Periodic Table

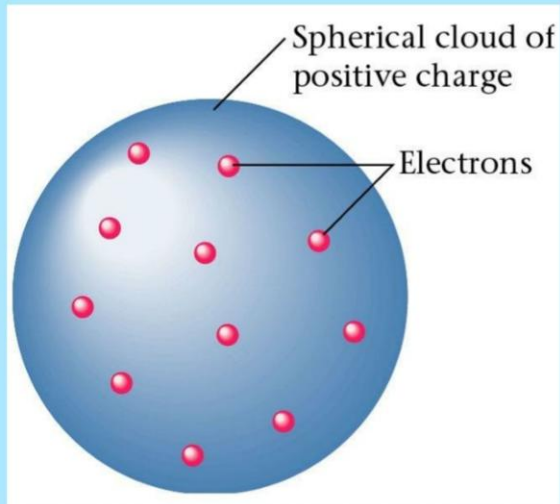


Group	I	II	III	IV	V	VI	VII	VIII			
Periods	A	B	A	B	A	B	A	B	Transition Series		
Oxides:	R ₂ O	RO	R ₂ O ₃	RO ₂	R ₂ O ₅	RO ₃	R ₂ O ₇	RO ₄			
Hydride :	RH	RH ₄	RH ₄	RH ₄	RH ₃	RH ₂	RH				
1.	H 1.008										
2.	Li 6.939	Be 9.012	B 10.81	C 12.011	N 14.007	O 15.999	F 18.998				
3.	Na 22.99	Mg 22.99	Al 24.31	Si 28.09	P 30.974	S 32.06	Cl 35.453				
4. First Series	K 39.102	Ca 40.08		Ti 47.90	V 50.94	Cr 50.20	Mn 54.94	Fe 55.85	Co 58.93	Ni 58.71	
Second Series		Cu 63.54			As 74.92		Se 78.96		Br 79.909		
5. First Series	Rb 85.47	Sr 87.62	Y 88.91	Zr 91.22	Nb 92.91	Mo 95.94	Tc 99	Ru 101.07	Rh 102.91	Pd 106.4	
Second Series		Ag 107.87			In 114.82		Sn 118.69		Sb 121.60	Te 127.60	I 126.90
6. First Series	Cs 132.90	Ba 137.34	La 138.91	Hf 178.40	Ta 180.95	W 183.85		Ru 190.2	Rh 192.2	Pd 195.09	
Second Series		Au 196.97			Tl 204.37		Pb 207.19		Bi 208.98		

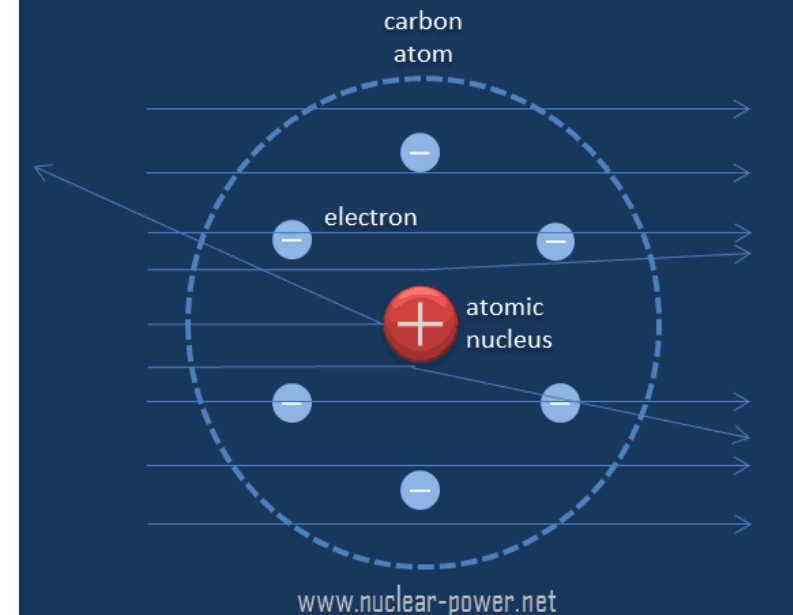
Turn of century – electrons and nuclei



Plum Pudding model of an atom.



Rutherford Model

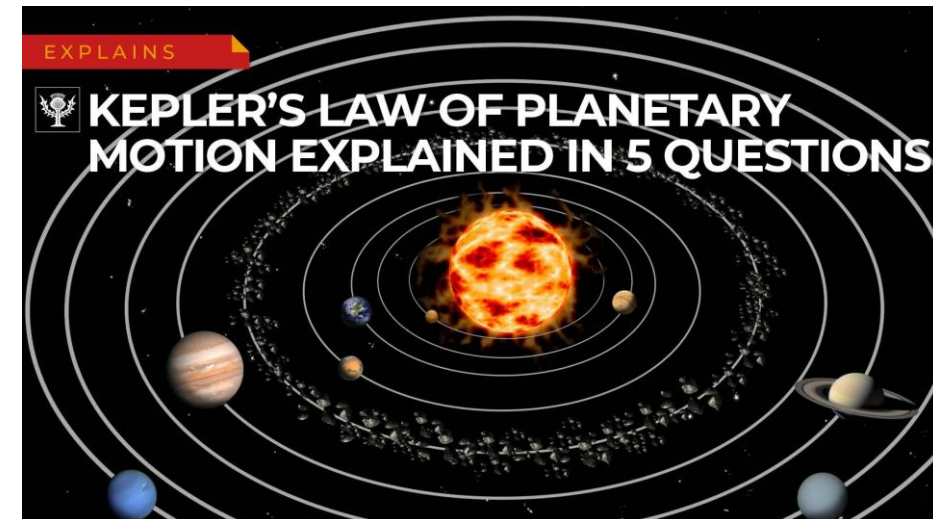
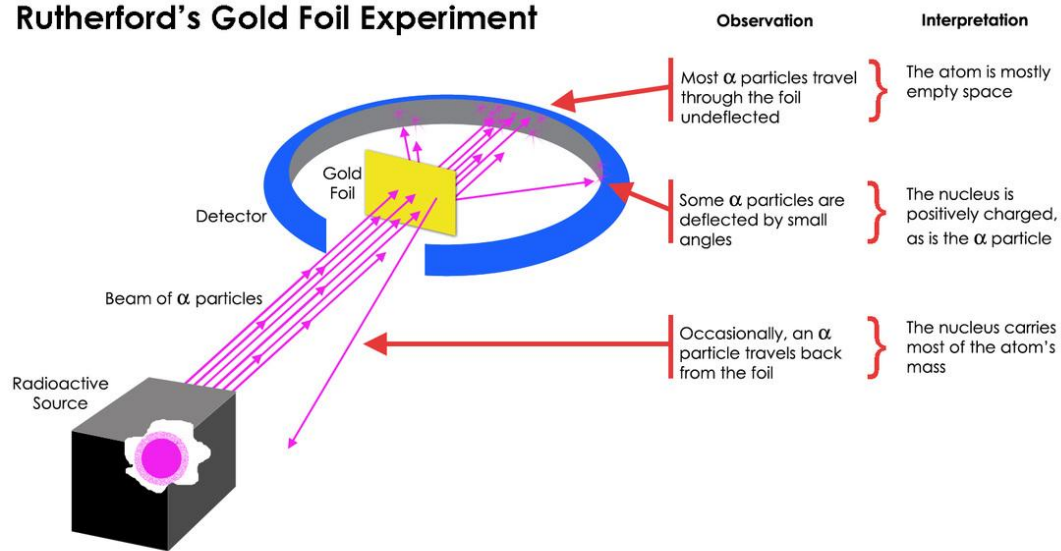


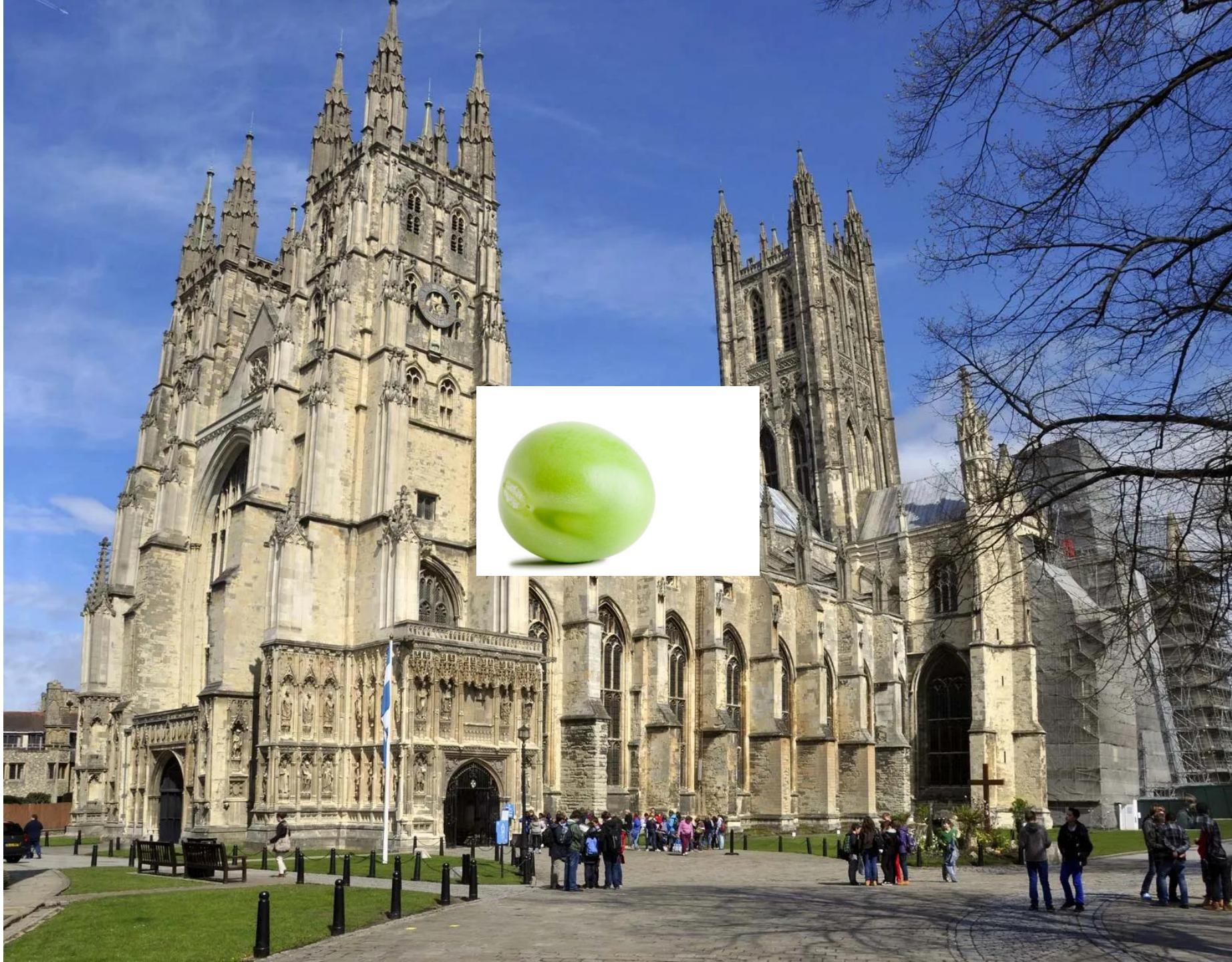
It actually took Rutherford some time to come to terms with his experiment that showed there was a nucleus in an atom.

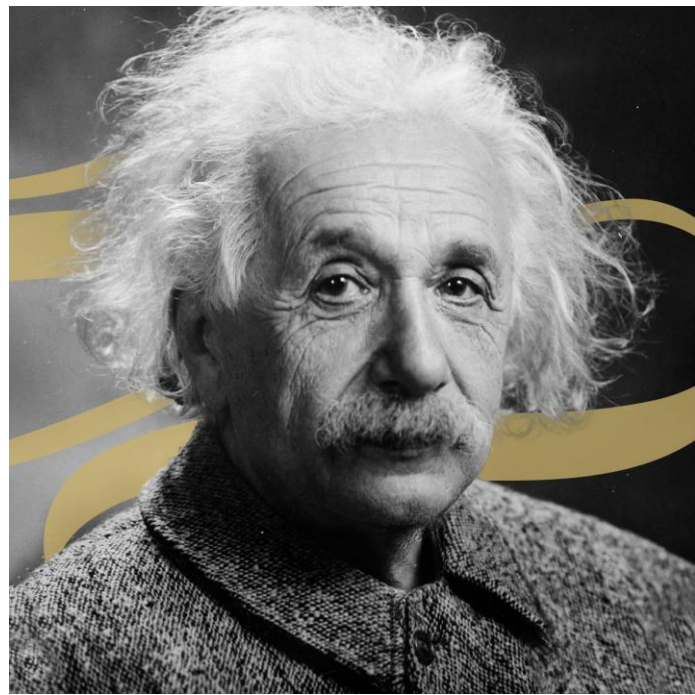
The experiment led to the rise of quantum mechanics and the 'strong force'.

Although it wasn't 1964 that Gell-Mann eventually came up with an explanation of the strong force

Rutherford's Gold Foil Experiment







And we really need the neutron as well



Atomic and nuclear properties common elements

Atomic electronic bonding

Sodium – 11p, 12n + Chlorine – 17p, 18n = common salt

Nuclear strong force structure

Same number of protons and neutrons but a new nucleus

Nickel – 28p, 30n

Note - As the elements become heavier, they have more neutrons than protons

And so - at last to the periodic table and the rare earths

Groups and Periods

Periodic Table of the Elements

1																		2										3										4										5										6										7										8										9										10										11										12										13										14										15										16										17										18									
IA																		IIA										IIIB										IVB										VB										VIB										VIIB										VIII										IIB										IIIB										IIIA										IVA										VA										VIA										VIIA										VIIIA																													
1A																		2A										3B										4B										5B										6B										7B										8										9										10										11B										12B										3A										4A										5A										6A										7A										8A									
1																		2										3										4										5										6										7										8										9										10										11										12										13										14										15										16										17										18									
H																		Li										Be										B										C										N										O										F										Ne										Na										Mg										Al										Si										P										S										Cl										Ar																			
Hydrogen																		Lithium										Beryllium										Boron										Carbon										Nitrogen										Oxygen										Fluorine										Neon										Sodium										Magnesium										Aluminum										Silicon										Phosphorus										Sulfur										Chlorine										Argon																			
1.008																		6.941										9.012										10.811										12.011										14.007										15.999										18.998										20.180										22.990										24.305										26.982										28.086										30.974										32.066										35.453										39.948																			
19																		20										21										22										23										24										25										26										27										28										29										30										31										32										33										34										35										36									
K																		Ca										Sc										Ti										V										Cr										Mn										Fe										Co										Ni										Cu										Zn										Ga										Ge										As										Se										Br										Kr									
Potassium																		Calcium										Scandium										Titanium										Vanadium										Chromium										Manganese										Iron										Cobalt										Nickel										Copper										Zinc										Gallium										Germanium										Arsenic										Selenium										Bromine										Krypton									
39.098																		40.078										44.956										47.88										50.942										51.996										54.938										55.933										58.933										58.693										63.546										65.39										69.723										72.61										74.922										78.972										79.904										84.80									
37																		38										39										40										41										42										43										44										45										46										47										48										49										50										51										52										53										54									
Rb																		Sr										Y										Zr										Nb										Mo										Tc										Ru										Rh										Pd										Ag										Cd										In										Sn										Sb										Te										I										Xe									
Rubidium																		Strontium										Yttrium										Zirconium										Niobium										Molybdenum										Technetium										Ruthenium										Rhodium										Palladium										Silver										Cadmium										Indium										Tin										Antimony										Tellurium										Iodine										Xenon									
84.468																		87.62										88.906										91.224										92.906										95.95										98.907										101.07										102.906										106.42										107.868										112.411										114.818										118.71										121.760										127.6										126.904										131.29									
55																		56										57-71										72										73										74										75										76										77										78										79										80										81										82										83										84										85										86									
Cs																		Ba										Lanthanide Series										Hf										Ta										W										Re										Os										Ir										Pt										Au										Hg										Tl										Pb										Bi										Po										At										Rn									
Cesium																		Barium										Lanthanum										Hafnium										Tantalum										Tungsten										Rhenium										Osmium										Iridium										Platinum										Gold										Mercury										Thallium										Lead										Bismuth										Polonium										Astatine										Radon									
132.905																		137.327										138.906										178.49										180.948										183.85										186.207										190.23										192.22										195.08										196.967										204.383										207.2										208.980										209.987										222.018																													
87																		88										89-103										104										105										106										107										108										109										110										111										112										113										114										115										116										117										118									
Fr																		Ra										Actinide Series										Rf										Db										Sg										Bh										Hs										Mt										Ds										Rg										Cn										Uut										Fl										Uup										Lv										Uus										Uuo									
Francium																		Radium										Actinium										Rutherfordium										Dubnium										Seaborgium										Bohrium										Hassium										Meitnerium										Darmstadtium										Roentgenium										Copernicium										Ununtrium										Flerovium										Ununpentium										Livermorium										Ununseptium										Ununoctium									
223.020																		226.025										227.028										261										262										265										264										269										268										269										272										277										unknown										[289]										unknown										[298]										unknown										[262]									

Lanthanide Series														Actinide Series															
57	58	59	60	61	62	63	64	65	66	67	68	69	70	71	89	90	91	92	93	94	95	96	97	98	99	100	101	102	103
La	Ce	Pr	Nd	Pm	Sm	Eu	Gd	Tb	Dy	Ho	Er	Tm	Yb	Lu	Ac	Th	Pa	U	Np	Pu	Am	Cm	Bk	Cf	Es	Fm	Md	No	Lr
Lanthanum	Cerium	Praseodymium	Neodymium	Promethium	Samarium	Europium	Gadolinium	Terbium	Dysprosium	Holmium	Erbium	Thulium	Ytterbium	Lutetium	Actinium	Thorium	Protactinium	Uranium	Neptunium	Plutonium	Americium	Curium	Berkelium	Californium	Einsteinium	Fermium	Mendelevium	Nobelium	Lawrencium
138.906	140.115	140.908	144.24	144.913	150.36	151.966	157.25	158.925	162.50	164.930	167.26	168.934	173.04	174.967	227.028	232.038	231.036	238.029	237.048	244.064	243.061	247.070	247.070	251.080	[254]	257.095	258.1	259.101	[262]

- Alkali Metal
- Alkaline Earth
- Transition Metal
- Basic Metal
- Semimetal
- Nonmetal
- Halogen
- Noble Gas
- Lanthanide
- Actinide

H 1																	He 2
Li 3	Be 4											B 5	C 6	N 7	O 8	F 9	Ne 10
Na 11	Mg 12											Al 13	Si 14	P 15	S 16	Cl 17	Ar 18
K 19	Ca 20	Sc 21	Ti 22	V 23	Cr 24	Mn 25	Fe 26	Co 27	Ni 28	Cu 29	Zn 30	Ga 31	Ge 32	As 33	Se 34	Br 35	Kr 36
Rb 37	Sr 38	Y 39	Zr 40	Nb 41	Mo 42	Tc 43	Ru 44	Rh 45	Pd 46	Ag 47	Cd 48	In 49	Sn 50	Sb 51	Te 52	I 53	Xe 54
Cs 55	Ba 56	La 57	Hf 72	Ta 73	W 74	Re 75	Os 76	Ir 77	Pt 78	Au 79	Hg 80	Tl 81	Pb 82	Bi 83	Po 84	At 85	Rn 86
Fr 87	Ra 88	Ac 89															

Lanthanides

Ce 58	Pr 59	Nd 60	Pm 61	Sm 62	Eu 63	Gd 64	Tb 65	Dy 66	Ho 67	Er 68	Tm 69	Yb 70	Lu 71
Th 90	Pa 91	U 92	Np 93	Pu 94	Am 95	Cm 96	Bk 97	Cf 98	Es 99	Fm 100	Md 101	No 102	Lr 103

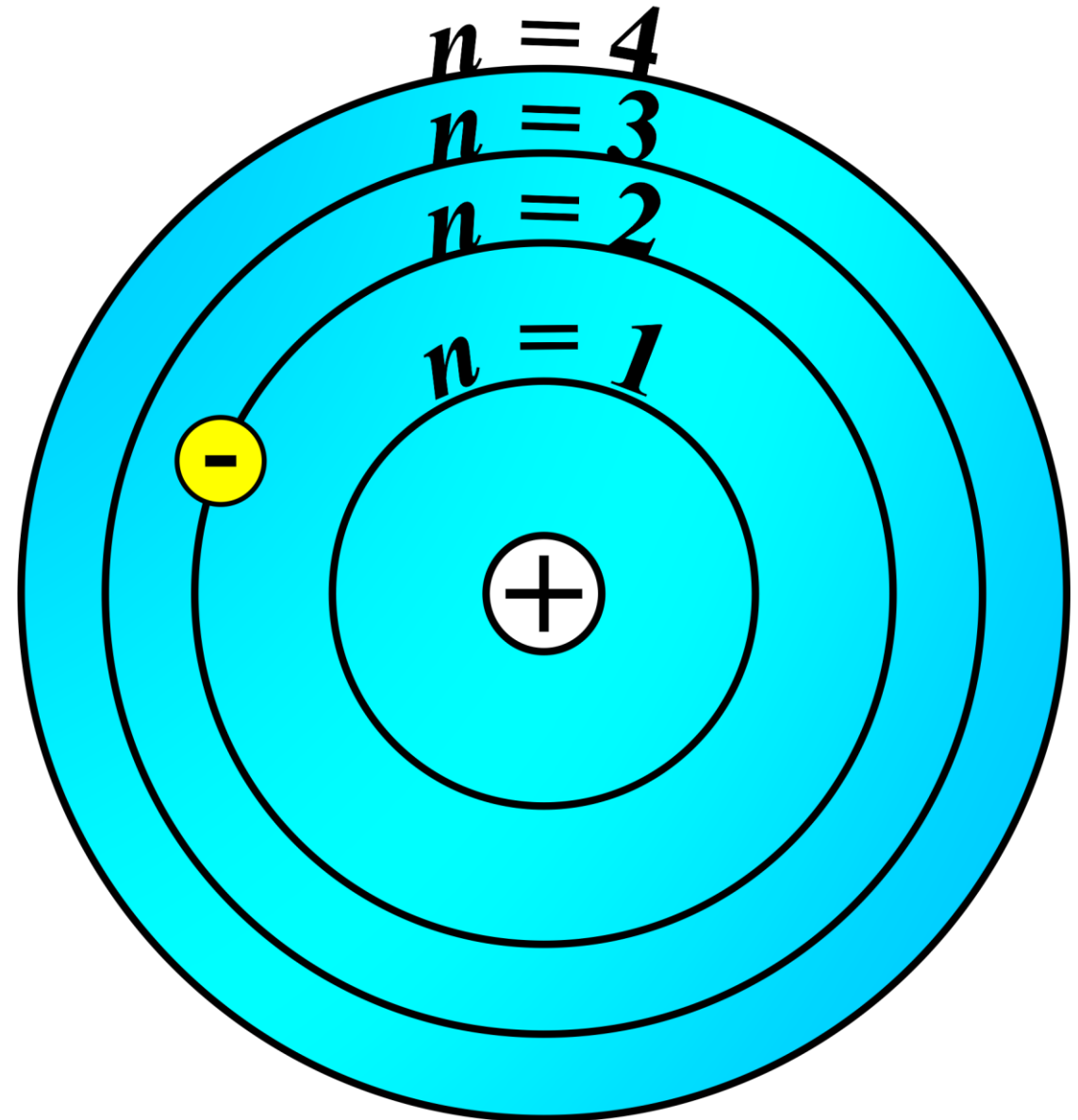
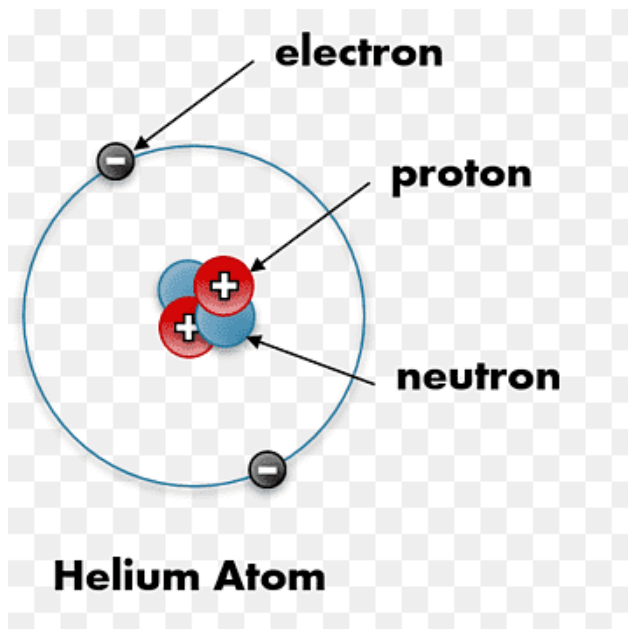
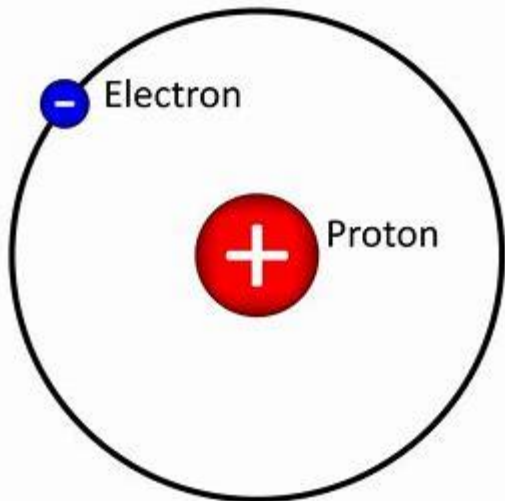
$$n : 4 \rightarrow 2$$

K, L, M

s, p, d, e, f

Quantum mechanics $2n^2$

Hydrogen atom



So, what exactly is going on?

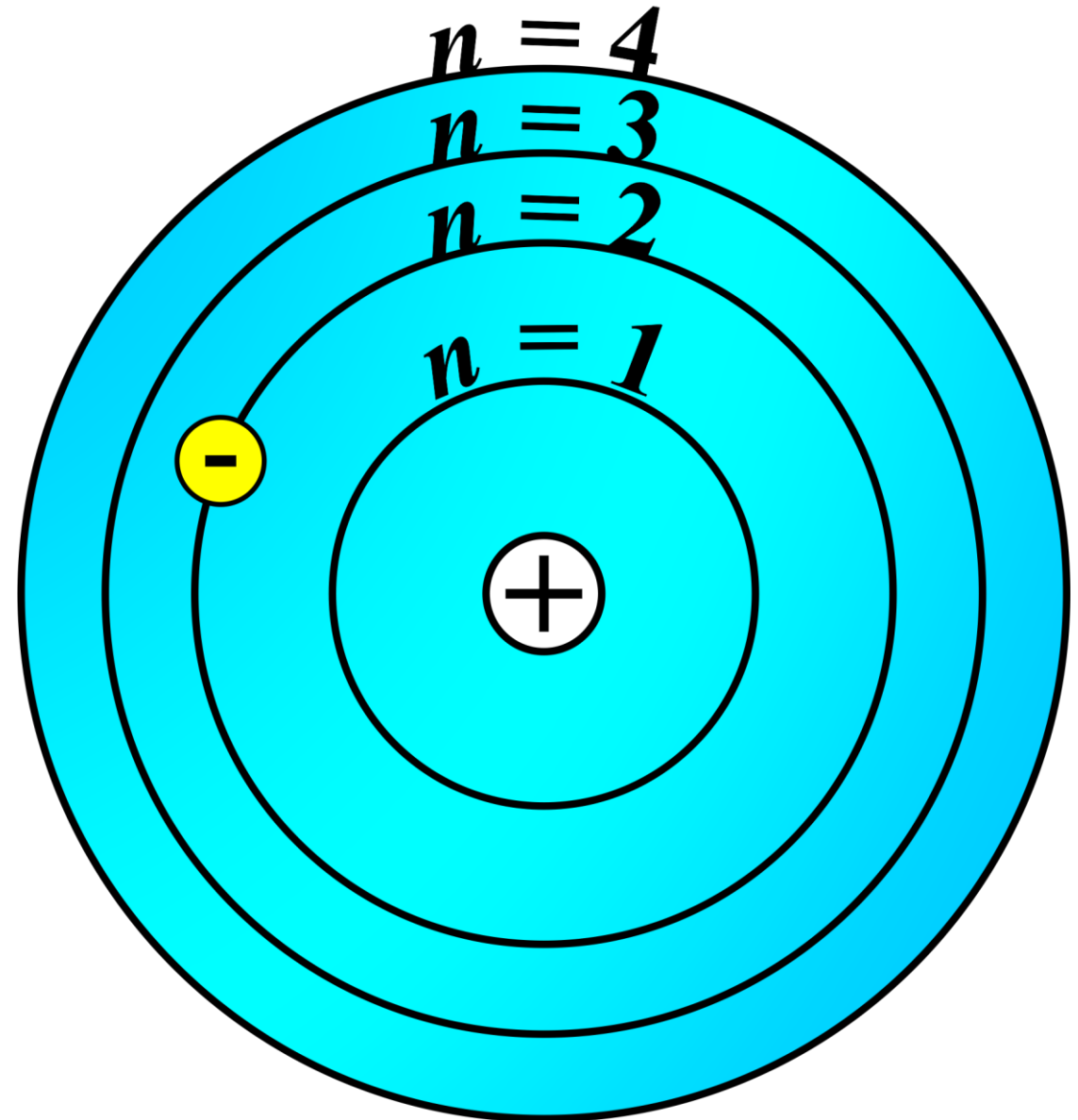
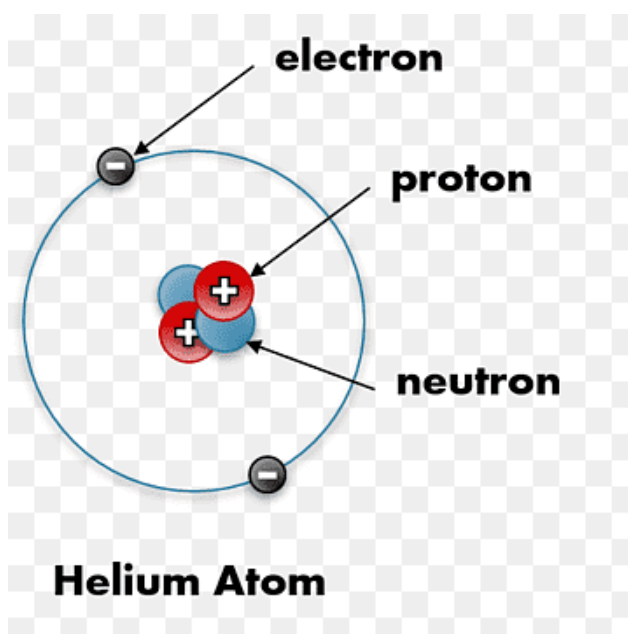
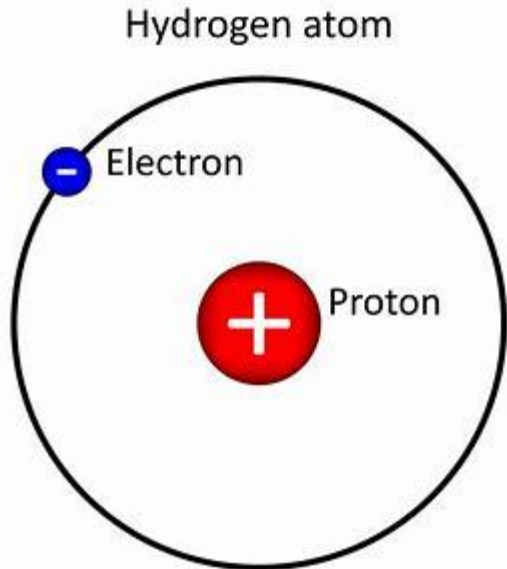


$$n : 4 \rightarrow 2$$

K, L, M

s, p, d, e, f

Quantum mechanics $2n^2$



Example (simple – they get worse!)

Neon (Ne) includes:

Atomic Structure: Neon has 10 protons, 10 neutrons, and 10 electrons arranged in two shells.

Electron Configuration: The electron configuration is $1s^2 2s^2 2p^6$, indicating a complete outer shell, which contributes to its chemical inertness.

Table 1.1 Structural and electronic properties (from Beaudry and Gschneidner 1978)

Element	Z	A	Electron	Radius / pm		Crystal Structure	Lattice Parameters			
			Config	Ionic	Metallic		a / pm	c / pm	c/a	
Scandium	Sc	21	45	$(3d4s)^3$	78.5	164.1	hcp	330.9	526.8	1.592
Yttrium	Y	39	89	$(4d5s)^3$	88.0	180.1	hcp	364.8	573.2	1.571
Lanthanum	La	57	139	$4f^0(5d6s)^3$	106.1	187.9	dhcp	377.4	1217.1	3.225
Cerium	Ce	58	140	$4f^1(5d6s)^3$	103.4	182.5	fcc	516.1	—	—
Praseodymium	Pr	59	141	$4f^2(5d6s)^3$	101.3	182.8	dhcp	367.2	1183.3	3.222
Neodymium	Nd	60	144	$4f^3(5d6s)^3$	99.5	182.1	dhcp	365.8	1179.7	3.225
Promethium	Pm	61	145	$4f^4(5d6s)^3$	97.9	181.1	dhcp	365	1165	3.19
Samarium	Sm	62	150	$4f^5(5d6s)^3$	96.4	180.4	rhom	362.9	2620.7	7.222
Europium	Eu	63	152	$4f^7(5d6s)^2$	95.0	204.2	bcc	458.3	—	—
Gadolinium	Gd	64	157	$4f^7(5d6s)^3$	93.8	180.1	hcp	363.4	578.1	1.591
Terbium	Tb	65	159	$4f^8(5d6s)^3$	92.3	178.3	hcp	360.6	569.7	1.580
Dysprosium	Dy	66	163	$4f^9(5d6s)^3$	80.8	177.4	hcp	359.2	565.0	1.573
Holmium	Ho	67	165	$4f^{10}(5d6s)^3$	89.4	176.6	hcp	357.8	561.8	1.570
Erbium	Er	68	167	$4f^{11}(5d6s)^3$	88.1	175.7	hcp	355.9	558.5	1.569
Thulium	Tm	69	169	$4f^{12}(5d6s)^3$	86.9	174.6	hcp	353.8	555.4	1.570
Ytterbium	Yb	70	173	$4f^{14}(5d6s)^2$	85.8	193.9	fcc	548.5	—	—
Lutetium	Lu	71	175	$4f^{14}(5d6s)^3$	84.8	173.5	hcp	350.5	554.9	1.583

Rare Earth elements – Lanthanides plus Sc and Y

Lately college parties never produce sexy European girls that drink heavily even though you look

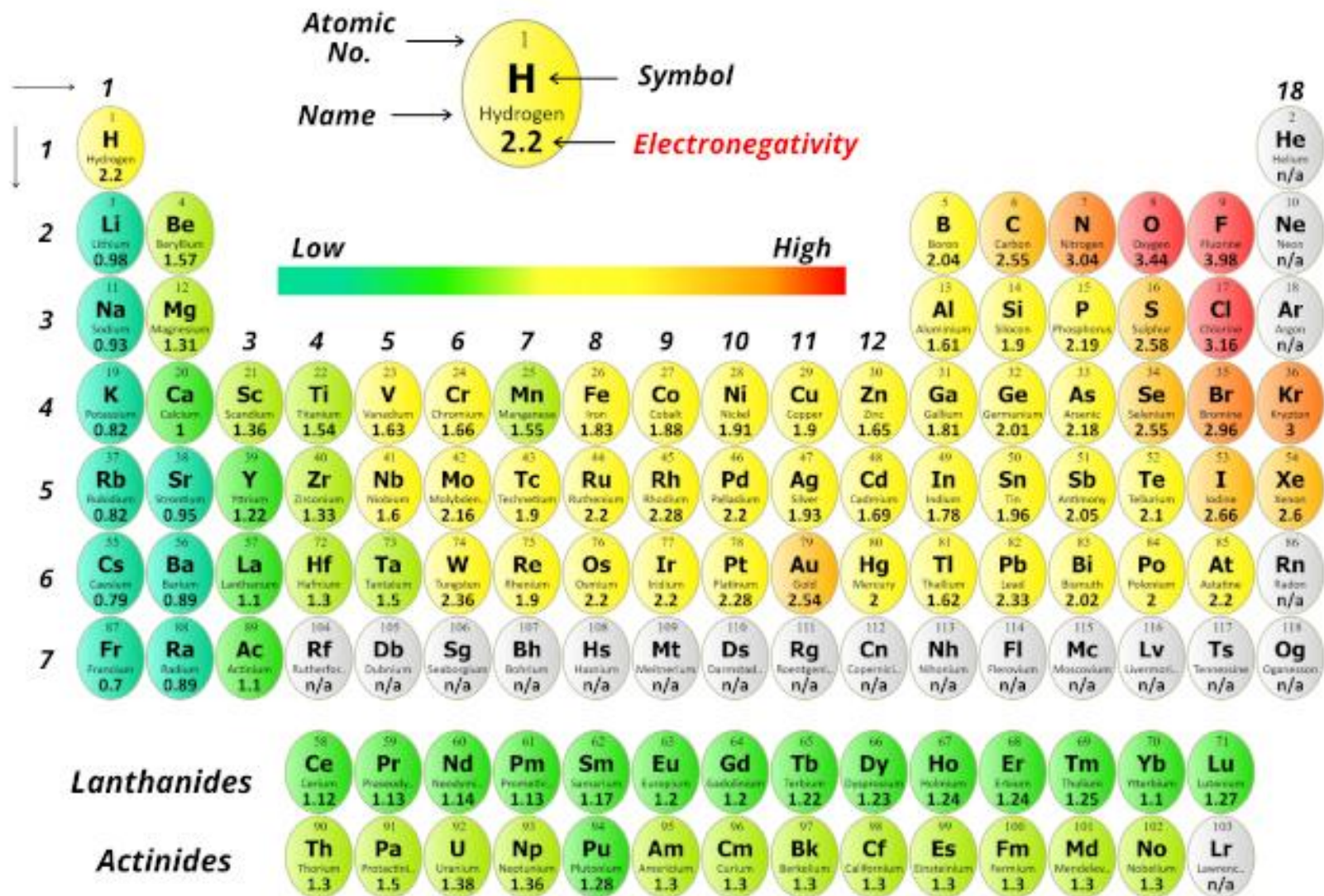
Periodic Table of the Elements

Atomic Number Melting Point
Symbol
 Name
 Atomic Mass

Normal melting points are in °C.
 TP = Triple Point
 Pressure is listed if not 1 atm.
 Allotrope is listed if more than one allotrope.

1 1A 1A 1 H Hydrogen 1.008 -259.1	2 IIA 2A 4 Be Beryllium 9.012 1287											13 IIIA 3A 5 B Boron 10.811 2075	14 IVA 4A 6 C Carbon 12.011 graphite 4489 TP (10.3 MPa)	15 VA 5A 7 N Nitrogen 14.007 -210	16 VIA 6A 8 O Oxygen 15.999 -218.79	17 VIIA 7A 9 F Fluorine 18.998 -219.67 TP	18 VIIIA 8A 2 He Helium 4.003 -272.20 (2.5 MPa)																															
3 Li Lithium 6.941 180.5	10 Ne Neon 20.180 -248.609 TP (43 kPa)											13 Al Aluminum 26.982 660.32	14 Si Silicon 28.086 1414	15 P Phosphorus 30.974 white 44.15	16 S Sulfur 32.066 115.21	17 Cl Chlorine 35.453 -101.5	18 Ar Argon 39.948 -189.36 TP (69 kPa)																															
11 Na Sodium 22.990 97.8	12 Mg Magnesium 24.305 650	3 III B 3B 21 Sc Scandium 44.956 1541	4 IV B 4B 22 Ti Titanium 47.88 1668	5 V B 5B 23 V Vanadium 50.942 1910	6 VI B 6B 24 Cr Chromium 51.996 1907	7 VII B 7B 25 Mn Manganese 54.938 1246	8 VIII 8 26 Fe Iron 55.933 1538	9 VIII 8 27 Co Cobalt 58.933 1495	10 VIII 8 28 Ni Nickel 58.693 1455	11 IB 1B 29 Cu Copper 63.546 1084.62	12 IIB 2B 30 Zn Zinc 65.39 419.53	31 Ga Gallium 69.732 29.76 TP	32 Ge Germanium 72.61 938.25	33 As Arsenic 74.922 817 TP (3.70 MPa)	34 Se Selenium 78.972 gray 220.8	35 Br Bromine 79.904 -7.2	36 Kr Krypton 84.80 -157.38 TP (73.2 kPa)																															
19 K Potassium 39.098 63.5	20 Ca Calcium 40.078 842	39 Y Yttrium 88.906 1522	40 Zr Zirconium 91.224 1855	41 Nb Niobium 92.906 2477	42 Mo Molybdenum 95.95 2623	43 Tc Technetium 98.907 2157	44 Ru Ruthenium 101.07 2334	45 Rh Rhodium 102.906 1964	46 Pd Palladium 106.42 1554.8	47 Ag Silver 107.868 961.78	48 Cd Cadmium 112.411 321.07	49 In Indium 114.818 156.6	50 Sn Tin 118.71 231.93	51 Sb Antimony 121.760 630.63	52 Te Tellurium 127.6 449.51	53 I Iodine 126.904 113.7	54 Xe Xenon 131.29 -111.74 TP (91.6 kPa)																															
37 Rb Rubidium 84.468 39.3	38 Sr Strontium 87.62 777	57-71		72 Hf Hafnium 178.49 2233	73 Ta Tantalum 180.948 3017	74 W Tungsten 183.85 3422	75 Re Rhenium 186.207 3185	76 Os Osmium 190.23 3033	77 Ir Iridium 192.22 2446	78 Pt Platinum 195.08 1768.2	79 Au Gold 196.967 1064.18	80 Hg Mercury 200.59 -38.83	81 Tl Thallium 204.383 304	82 Pb Lead 207.2 327.46	83 Bi Bismuth 208.980 271.4	84 Po Polonium [208.982] 254	85 At Astatine 209.987 302	86 Rn Radon 222.018 -71																														
55 Cs Cesium 132.905 28.44	56 Ba Barium 137.327 727	89-103		104 Rf Rutherfordium [261] unknown	105 Db Dubnium [262] unknown	106 Sg Seaborgium [266] unknown	107 Bh Bohrium [264] unknown	108 Hs Hassium [269] unknown	109 Mt Meitnerium [268] unknown	110 Ds Darmstadtium [269] unknown	111 Rg Roentgenium [272] unknown	112 Cn Copernicium [277] unknown	113 Uut Ununtrium unknown [288]	114 Fl Flerovium [289] unknown	115 Uup Ununpentium unknown [288]	116 Lv Livermorium [293] unknown	117 Uus Ununseptium unknown [294]	118 Uuo Ununoctium unknown [294]																														
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This is a **Periodic table with Electronegativity values** labeled on it.

You can also download High resolution **Electronegativity chart** from this article. **(It's Free)**

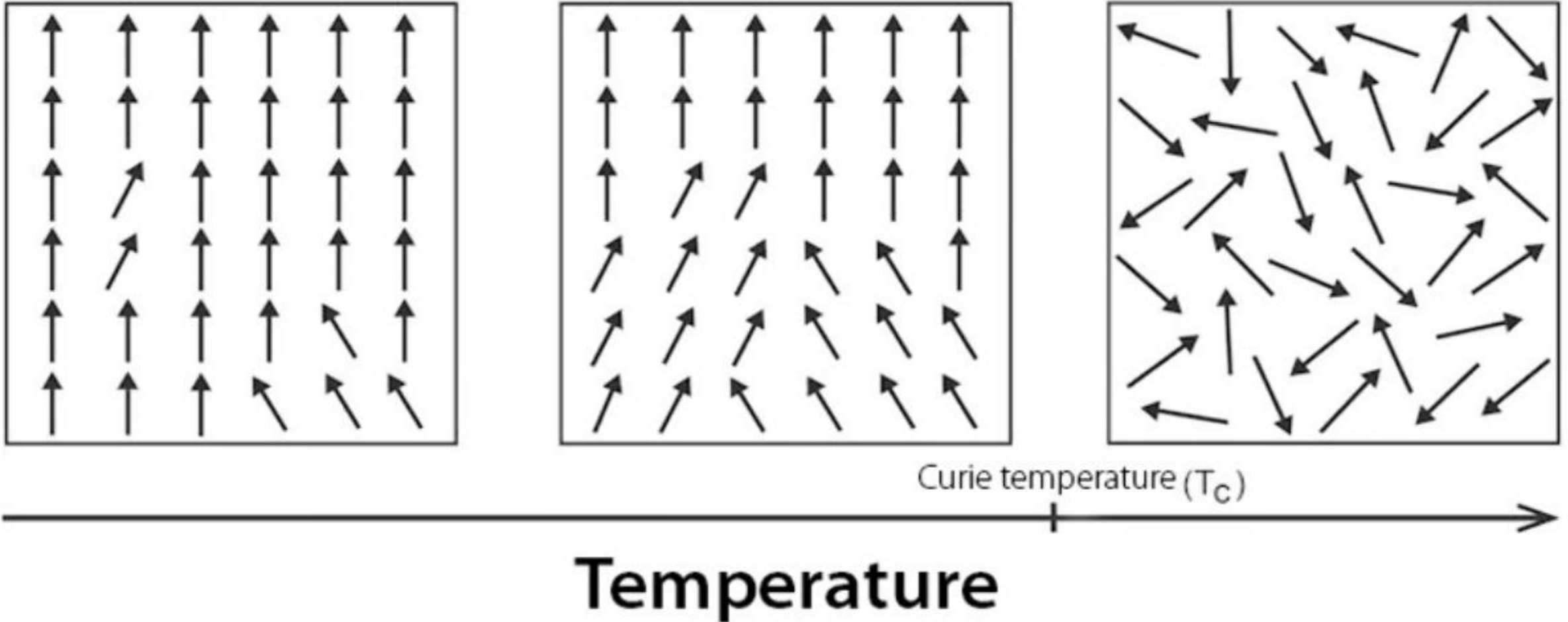
Rare Earths have different properties

This has been the topic of extensive study and includes some complex explanations.

Spin orbit coupling – angular momentum – total momentum – quantum state.

Largely dictated by the effect of the increasing number of electrons in the 4f shell.

Curie Temperature



Magnetic Properties

- Includes neodymium (Nd), dysprosium (Dy), and samarium (Sm)
- These rare earth elements are particularly valued for their magnetic properties. Magnetic fields are generated by unpaired electrons aligned so they spin in the same direction. The orbital electron structure of these elements contains many unpaired electrons, which means these rare earth materials can store large amounts of magnetic energy. A **neodymium** magnet can store about 18 times more magnetic energy than an iron magnet of the same volume. Rare earth magnets are widely used today in many applications, including wind turbines, electric motors, guidance systems on aircraft and missiles, speakers for personal electronics, and computer hard drives.
- Unfortunately, in their pure form these rare earth elements lose their magnetism before they reach room temperature. To ensure that these rare earth metals retain their magnetism, they are combined with a transition metal, such as iron or cobalt. The resulting metal alloys display great magnetic strength and retain their magnetism at higher temperatures. Examples of these alloys are **neodymium**-iron-boron magnets ($\text{Nd}_2\text{Fe}_{14}\text{B}$) and **samarium**-cobalt (SmCo_5) magnets. Neodymium alloys are quite brittle, however, and need to be coated with other metals to produce magnets that do not break apart under ordinary use. The need to remove these coatings increases the cost of recycling rare earth magnets.

Separation

We have separated materials with similar properties in the past

U235 and U238 – need to enhance concentration of U235 relative to U238

Use mass sensitive techniques – diffusion and centrifuges

These are very difficult processes and will not work for the rare earths as there is not sufficient mass difference – it also requires vast separation plants.

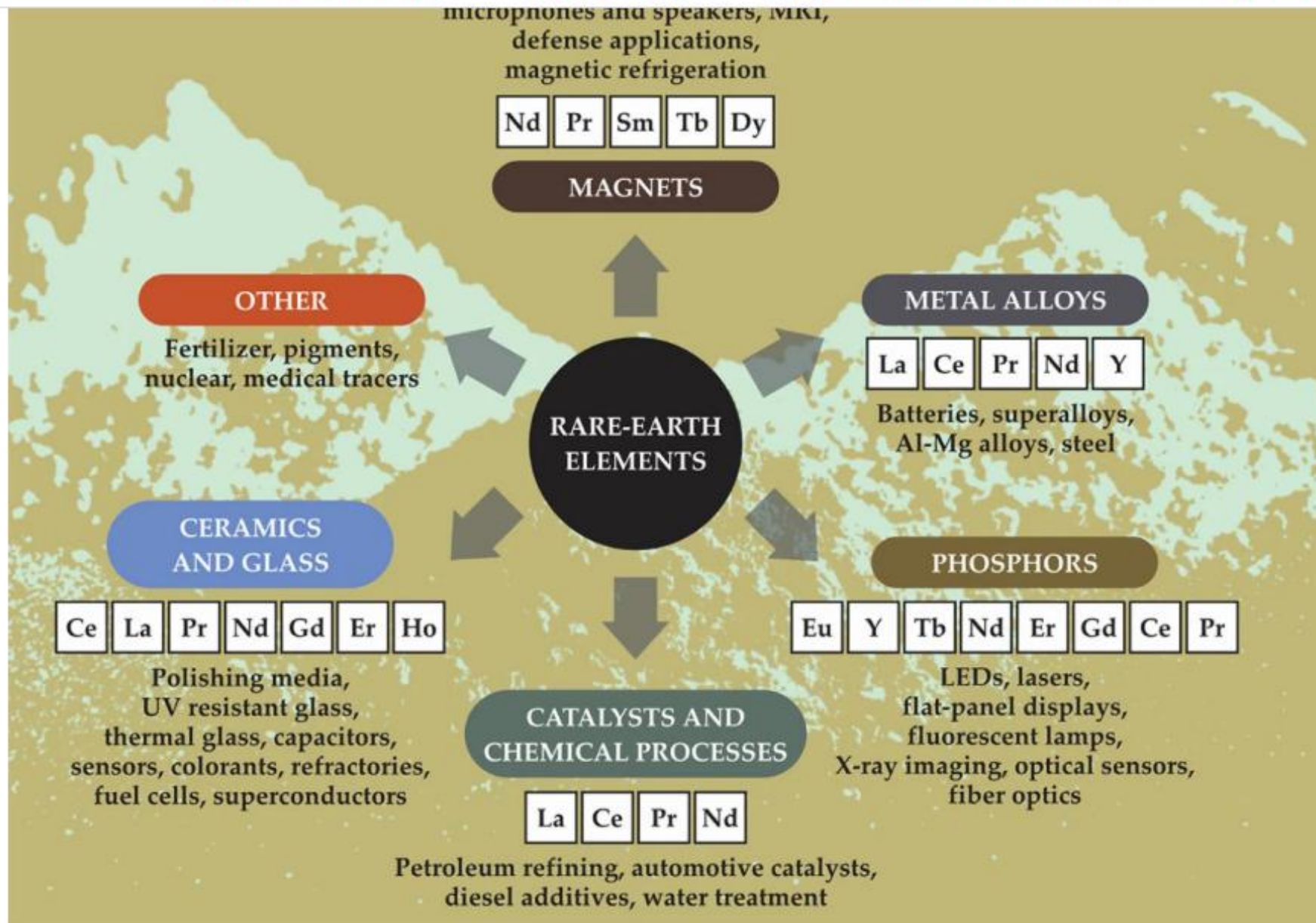
Solubility

If we have two immiscible liquids with a difference in solubility for rare earths they can be separated by repeated dissolving and splitting.

It is a terribly inefficient process – it takes ages - uses lots of nasty solvents – and energy - and is an environmental nightmare.

That was why the US stopped mining their rare earths

The Chinese don't care – in their own country and without – but are the true experts in this refining process



Dozens of applications use rare-earth elements as key ingredients. [View larger](#)

Final slide – topics for debate

Rare Earths – named for strange properties rather than for being rare.

Found from mid 18th Century – initially near town of Ytterby in Sweden.

Main research conducted after the US set up a programme in 1967.

Abundance – Environment – Political control – Future use - etc

Debate

I'm sure we all know that Rare Earths are in the news – Demented Donald and more sensible people.

However, consider this point.

There are approx. 8B people and the world can only realistically survive with approx. 2B

Most of our problems are about the need to resource what people want – destroying the Amazonian rain forest – AI requirements etc.

I do not know the answers – I just stick to the technical bits.

Tea break

