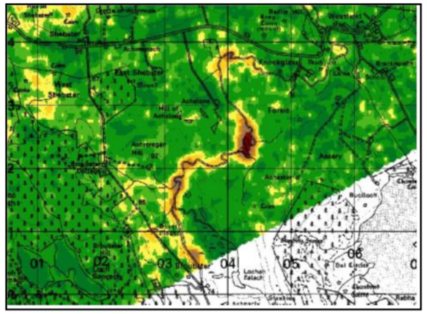
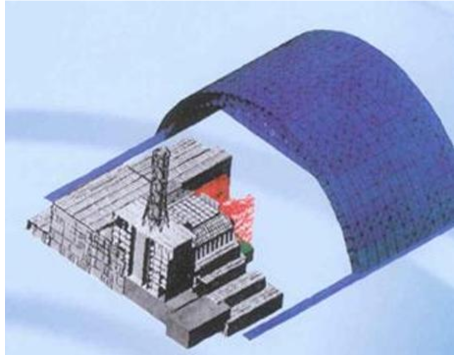
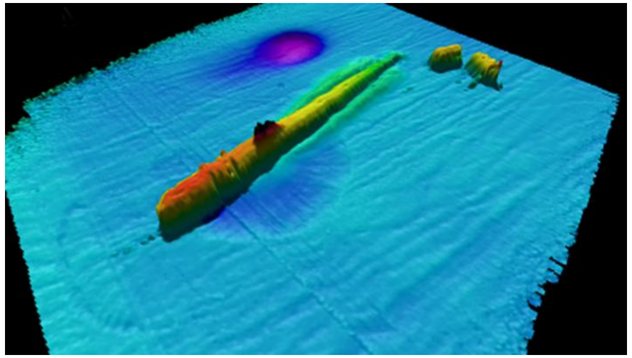
Me

- 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…..

Didcot First
Connecting Business and Community

3rd - March – Julian – Google AI

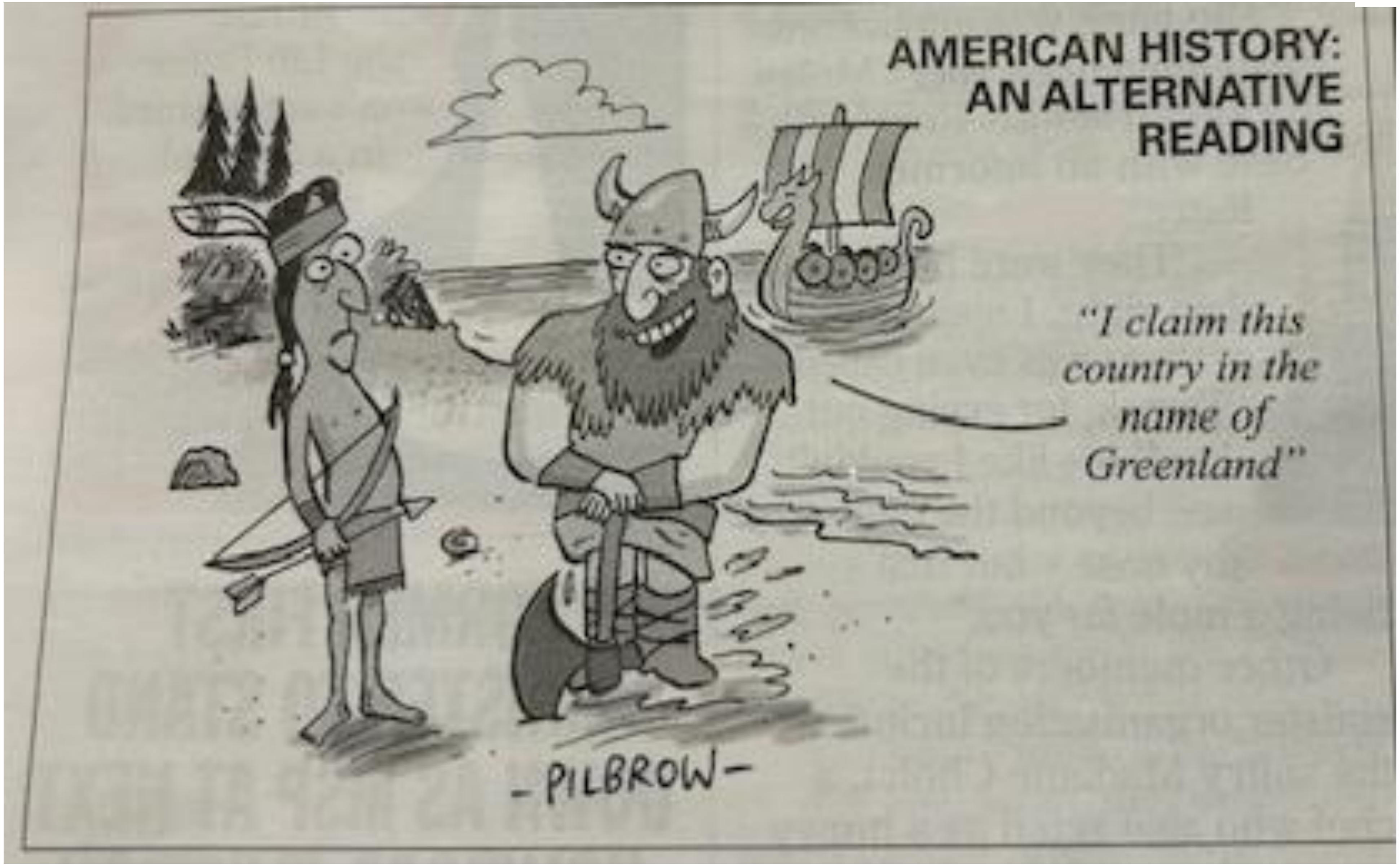
7th April – Paul Le Blond – South Bucks – Frank Whittle and the Jet Engine

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

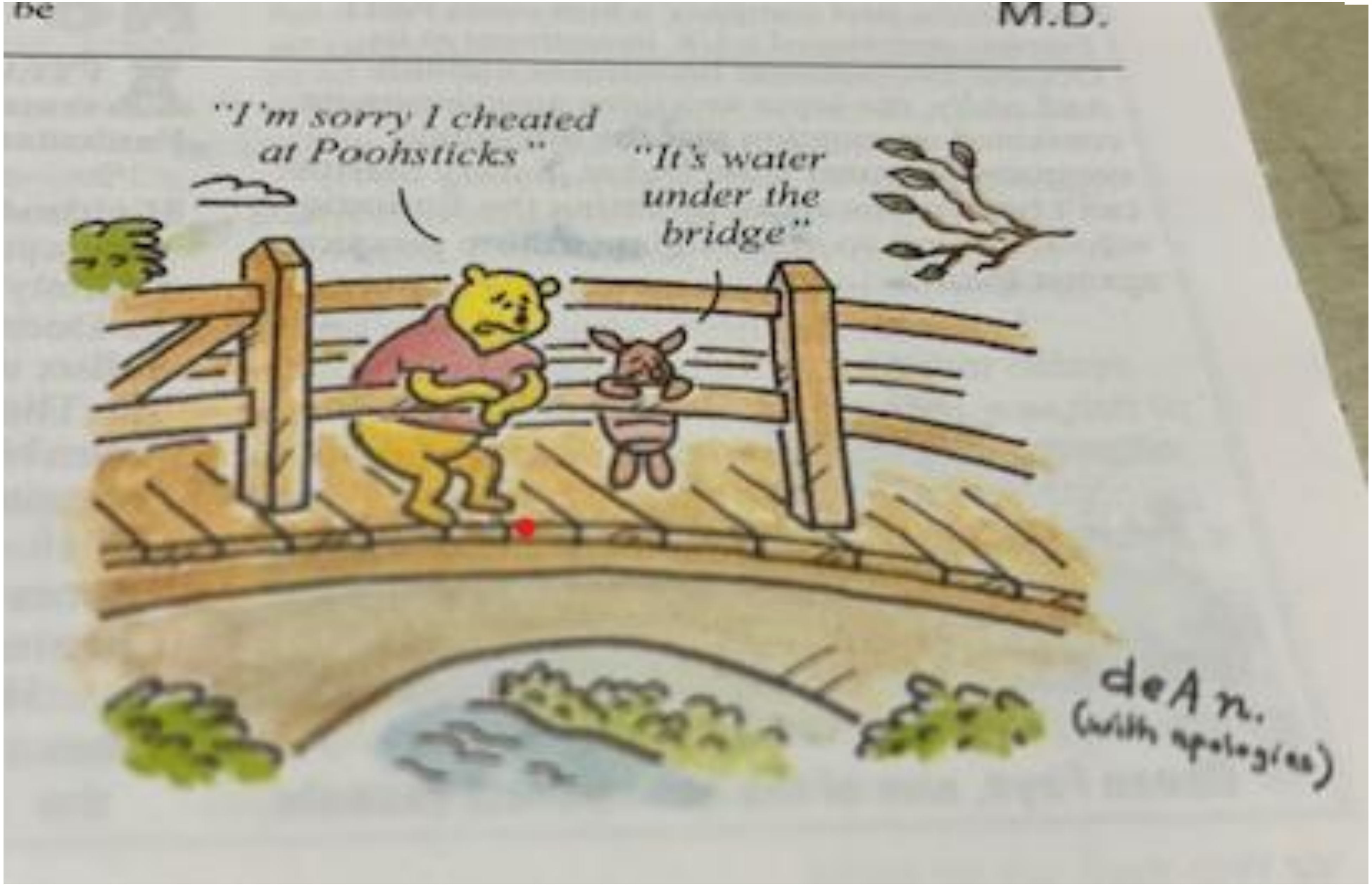
2nd June - Janet High – NHS screening – should more cancers be included?

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

"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-

Didcot First
Connecting Business and Community



Didcot First
Connecting Business and Community


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

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 I 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

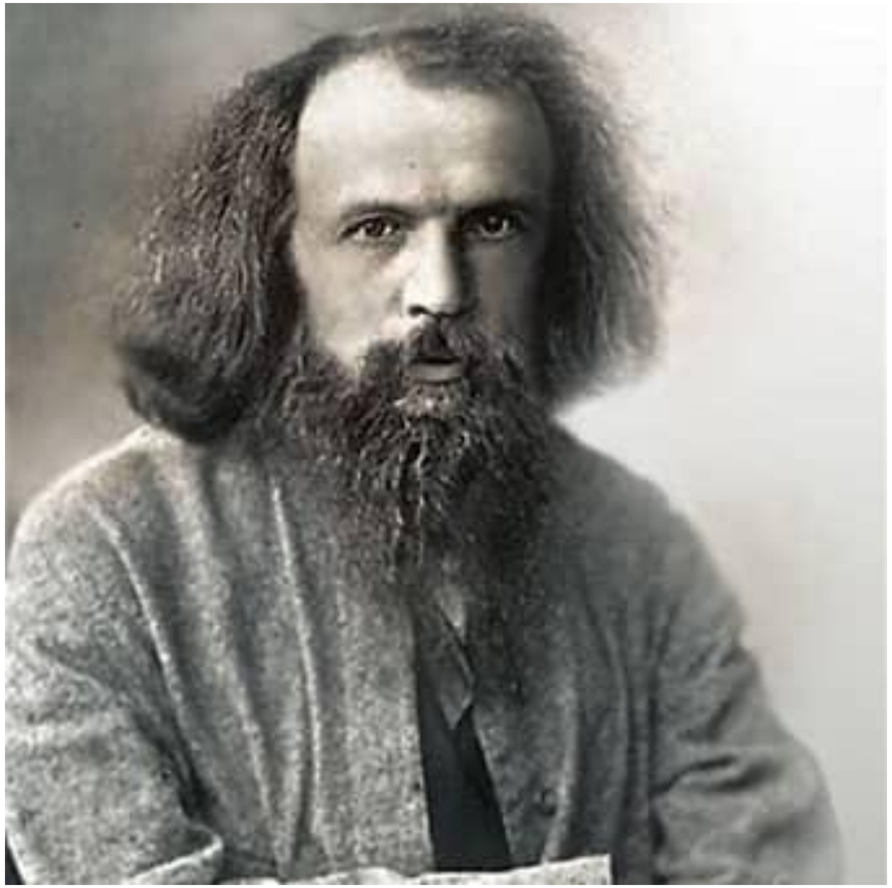
An element can be essentially defined as an atom with a nucleus that contain a specific number of protons – and thus the same number of atomic electrons

Hydrogen 1, Helium 2, Iron 26 etc

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

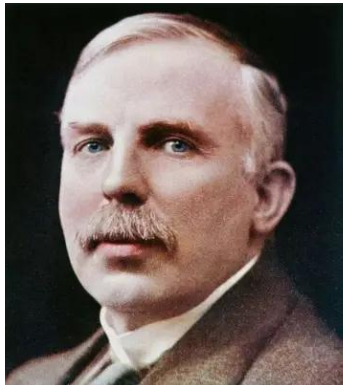
I	II	III	IV	V	VI	VII	VIII		
H 1.01									
Li 6.94	Be 9.01	B 10.8	C 12.0	N 14.0	O 16.0	F 19.0			
Na 23.0	Mg 24.3	Al 27.0	Si 28.1	P 31.0	S 32.1	Cl 35.5			
K 39.1	Ca 40.1		Ti 47.9	V 50.9	Cr 52.0	Mn 54.9	Fe 55.9	Co 58.9	Ni 58.7
Cu 63.5	Zn 65.4			As 74.9	Se 79.0	Br 79.9			
Rb 85.5	Sr 87.5	Y 88.9	Zr 91.2	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	Ti 204	Pb 207	Bi 209					
				Th 232		U 238			

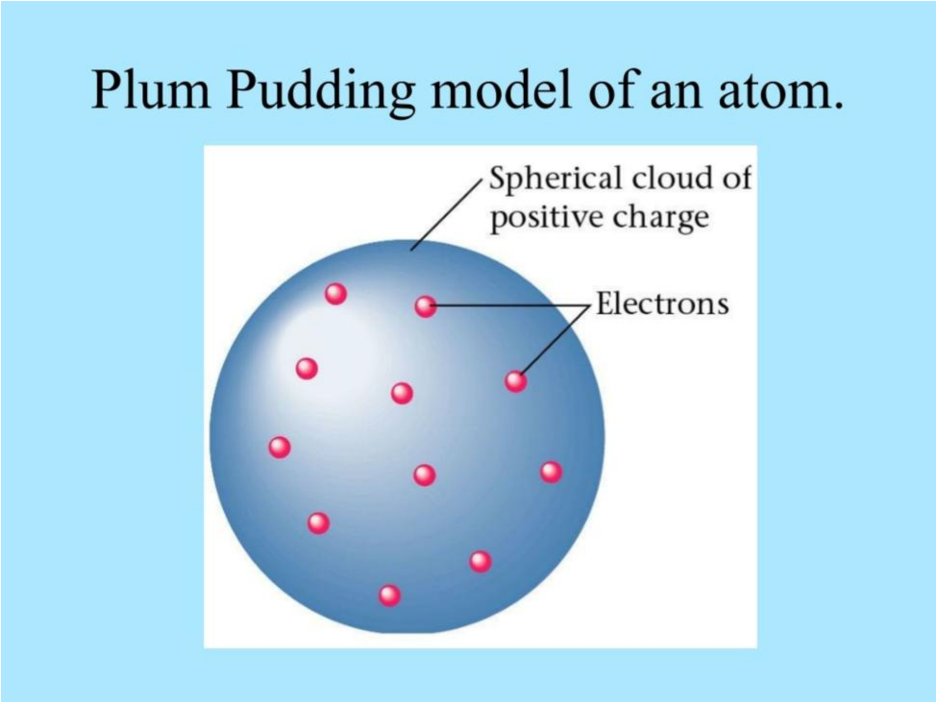
Mendeleev's Periodic Table

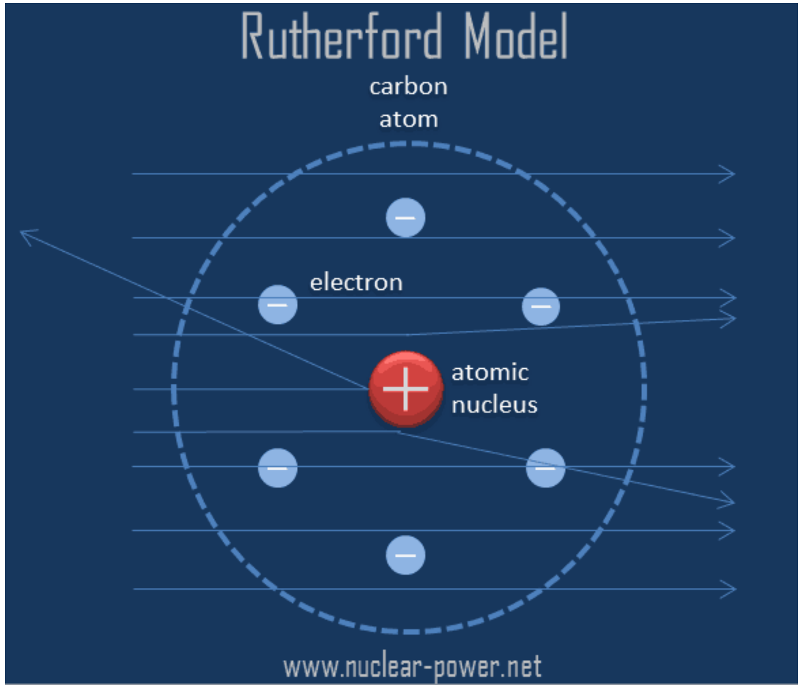


Group	I	II	III	IV	V	VI	VII	VIII
Periods	A B	A B	A B	A B	A B	A B	A B	Transition Series
Oxides: Hydride:	R_2O RH	RO RH_4	R_2O_3 RH_4	RO_2 RH_4	R_2O_5 RH_3	RO_3 RH_2	R_2O_7 RH	RO_4
1.	H 1.008							
2.	Li 6.939	Be 9.012	B 10.81	C 12.011	N 14.007	O 15.999	F 18.998	
3.	Na 22.99	Mg 22.99	Al 24.31	Si 28.09	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 Co Ni 55.85 58.93 58.71
Second Series	Cu 63.54	Zn 65.54			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 Rh Pd 101.07 102.91 106.4
Second Series	Ag 107.87	Cd 112.40	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 Rh Pd 190.2 192.2 195.09
Second Series	Au 196.97	Hg 200.59	Tl 204.37	Pb 207.19	Bi 208.98			

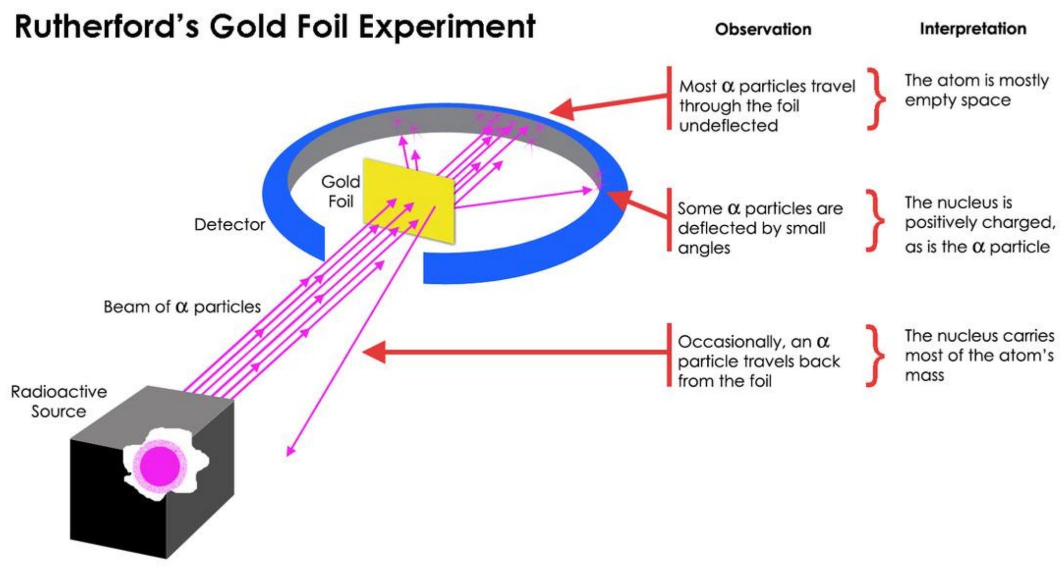
Turn of century – electrons and nuclei

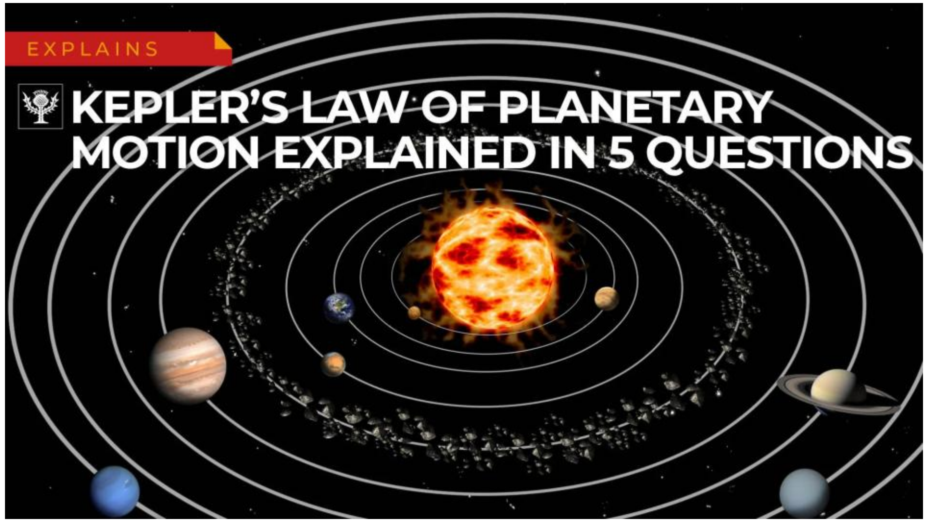


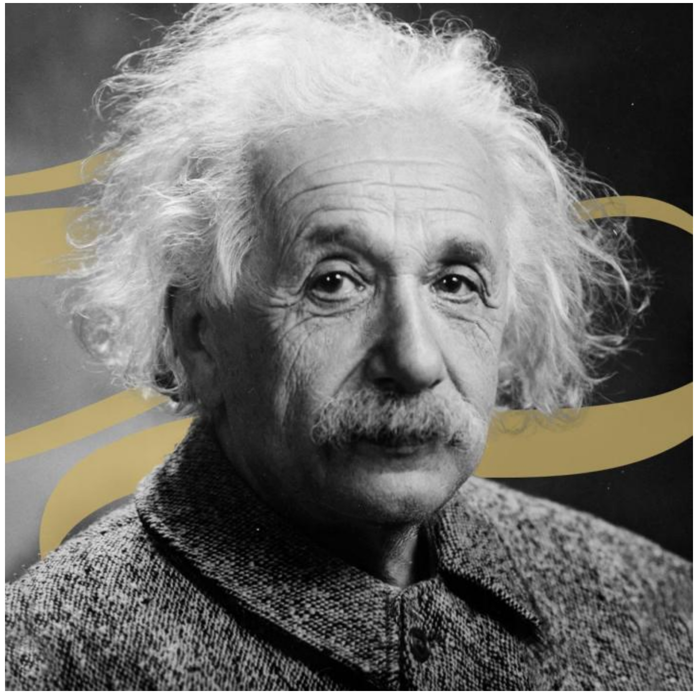




It actually took Rutherford some time to come to terms with his experiment that showed there was a nucleus in an atom.
The experiment led to the rise of quantum mechanics and the 'strong force'.
Although it wasn't 1964 that Gell-Mann eventually came up with an explanation of the strong force






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

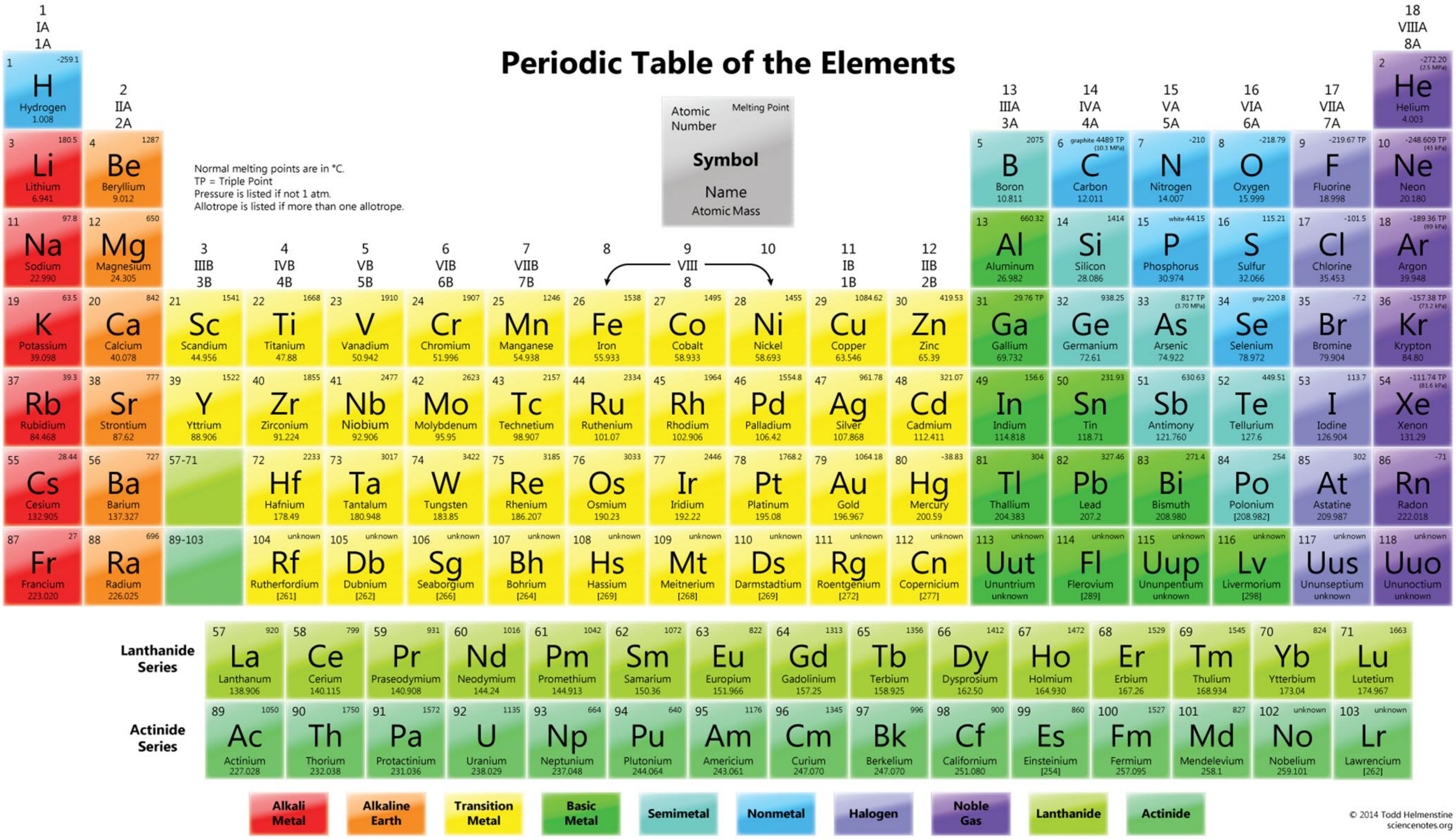
Nuclear strong force structure

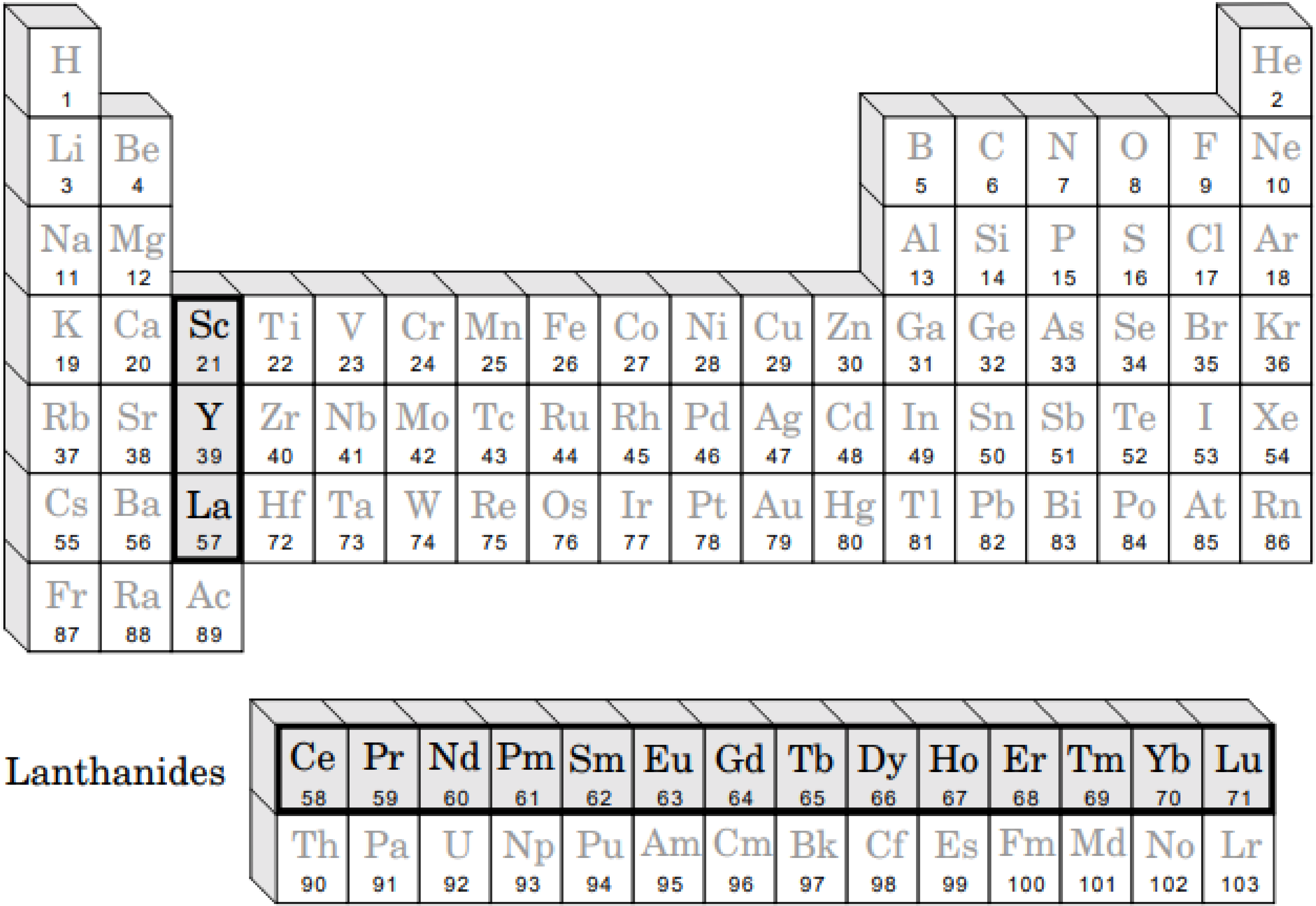
Same number of protons and neutrons but a new nucleus

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



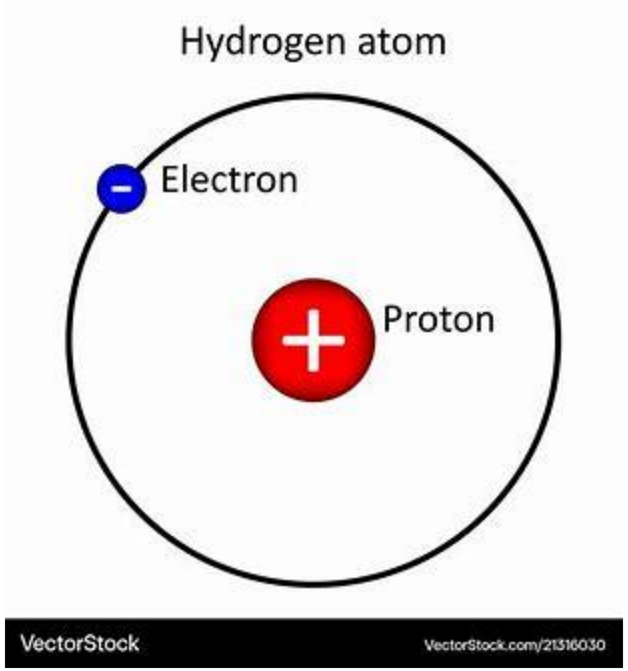

H 1
He 2
Li 3 Be 4 B 5 C 6 N 7 O 8 F 9 Ne 10
Na 11 Mg 12 Al 13 Si 14 P 15 S 16 Cl 17 Ar 18
K 19 Ca 20 Sc 21 Ti 22 V 23 Cr 24 Mn 25 Fe 26 Co 27 Ni 28 Cu 29 Zn 30 Ga 31 Ge 32 As 33 Se 34 Br 35 Kr 36
Rb 37 Sr 38 Y 39 Zr 40 Nb 41 Mo 42 Tc 43 Ru 44 Rh 45 Pd 46 Ag 47 Cd 48 In 49 Sn 50 Sb 51 Te 52 I 53 Xe 54
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

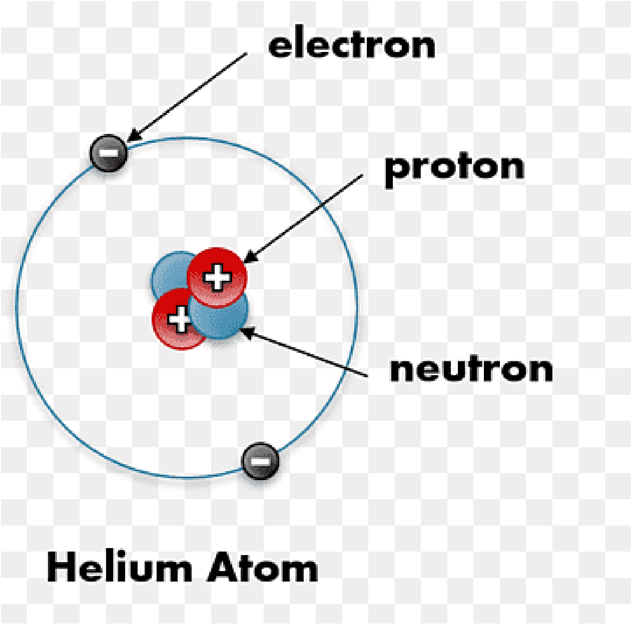
$$n : 4 \rightarrow 2$$

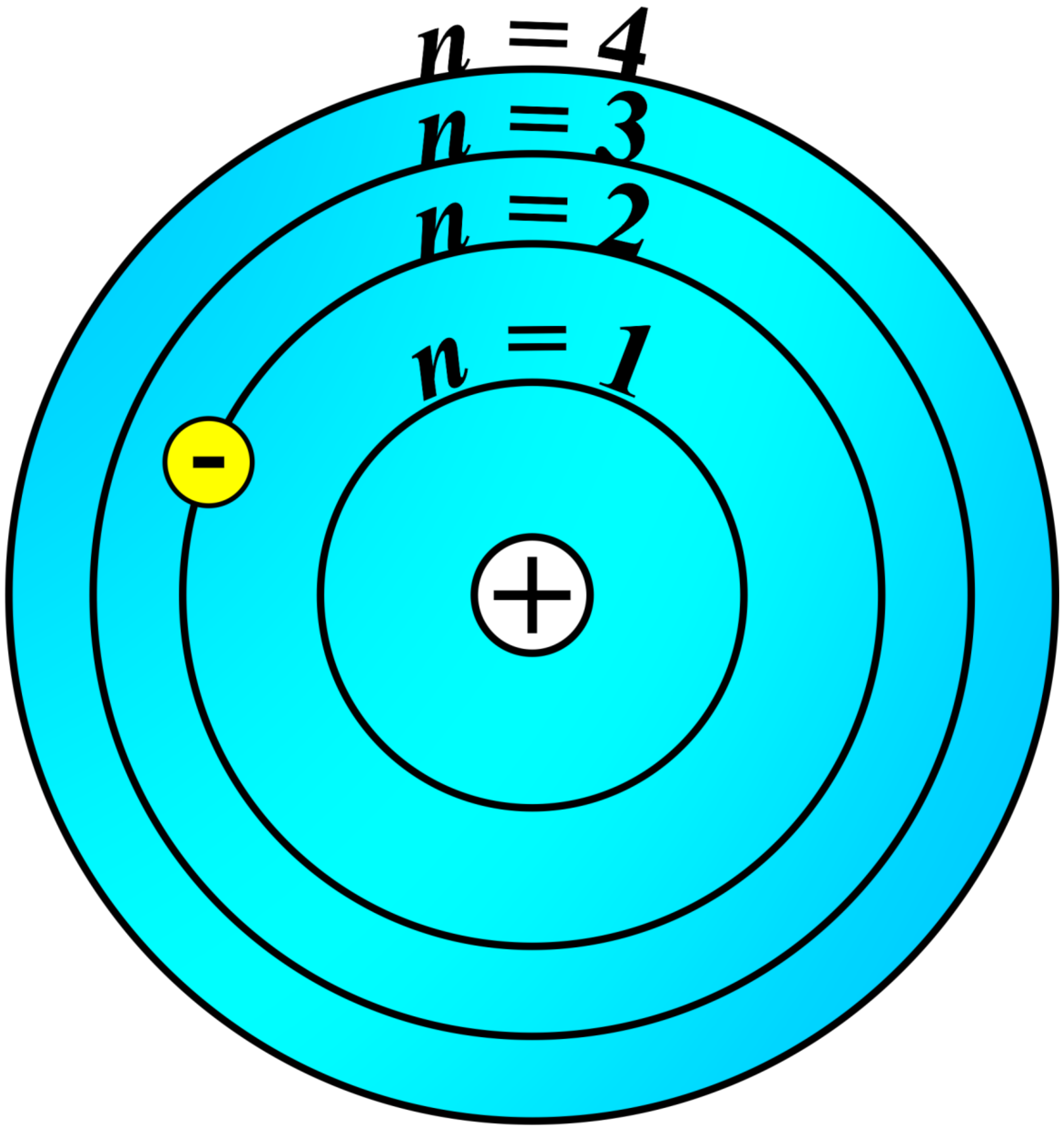
K, L, M

s, p, d, e, f

Quantum mechanics $2n^2$







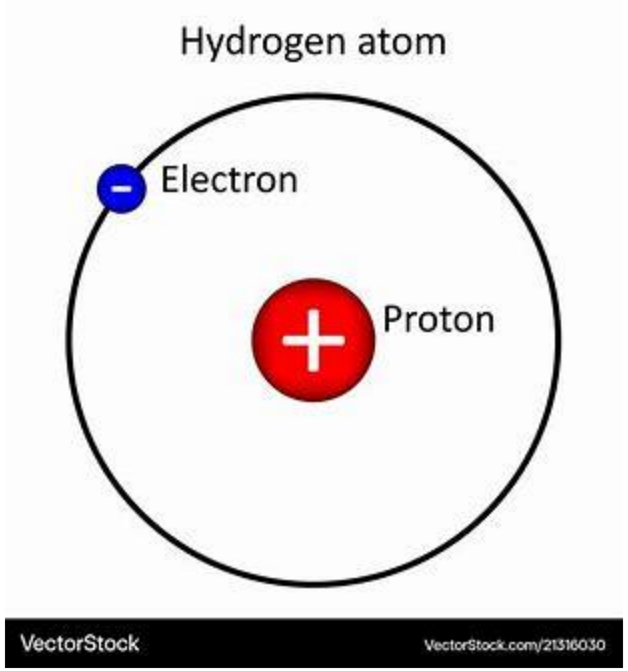
So, what exactly is going on?

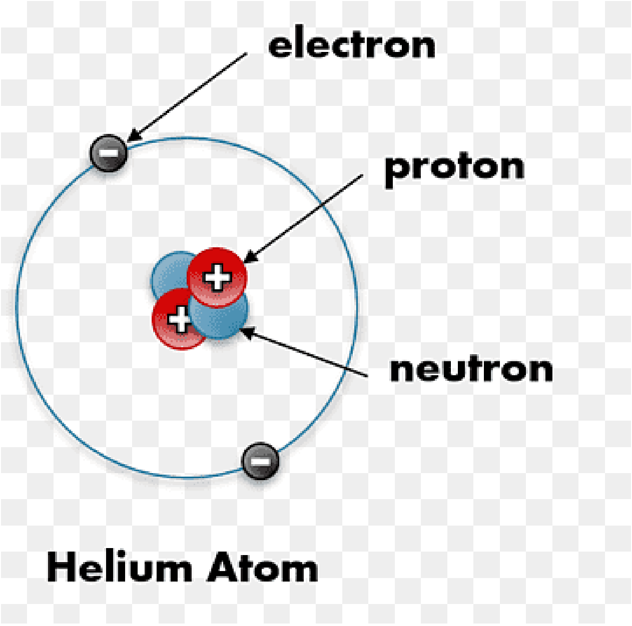
$$n : 4 \rightarrow 2$$

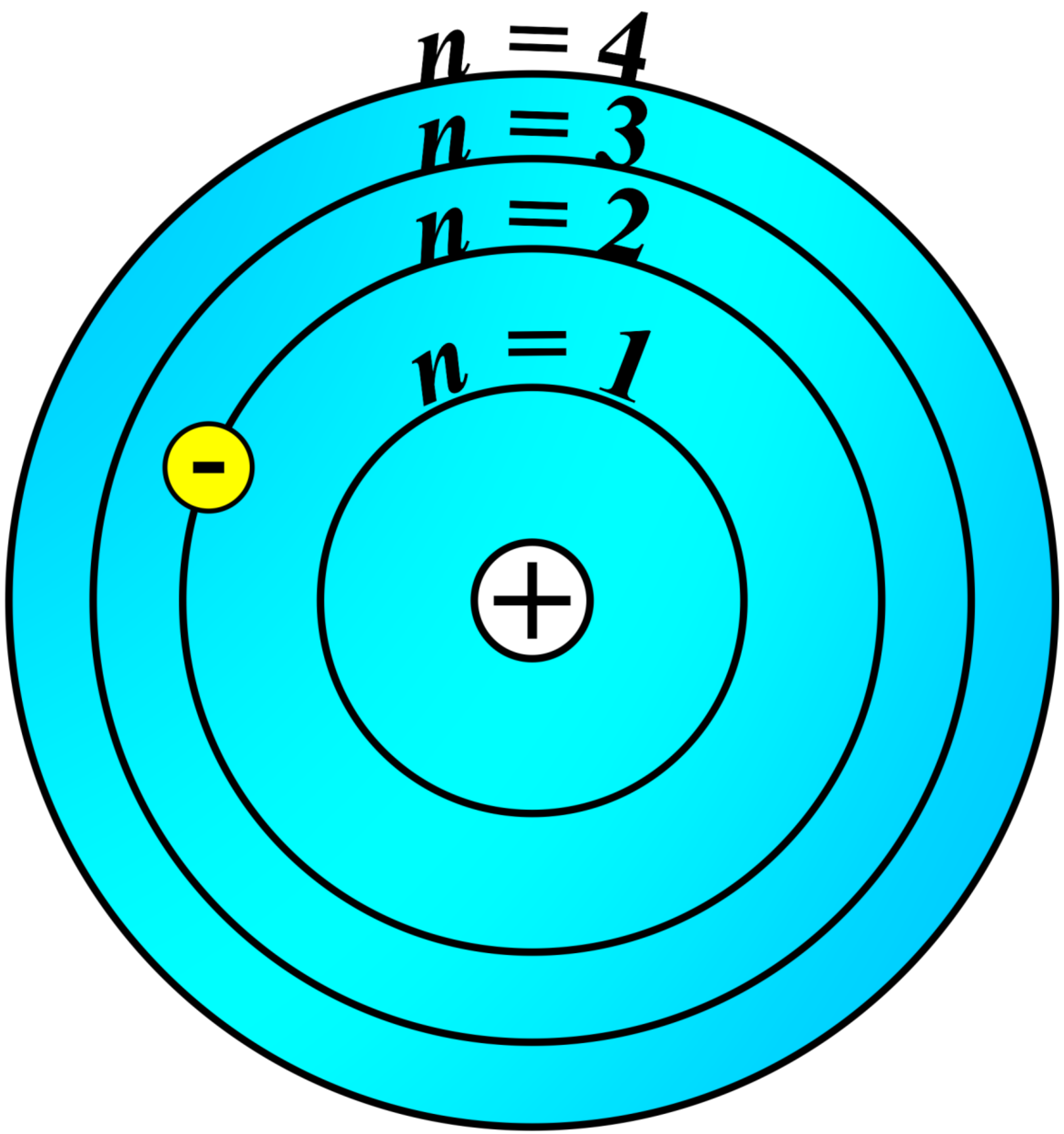
K, L, M

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.

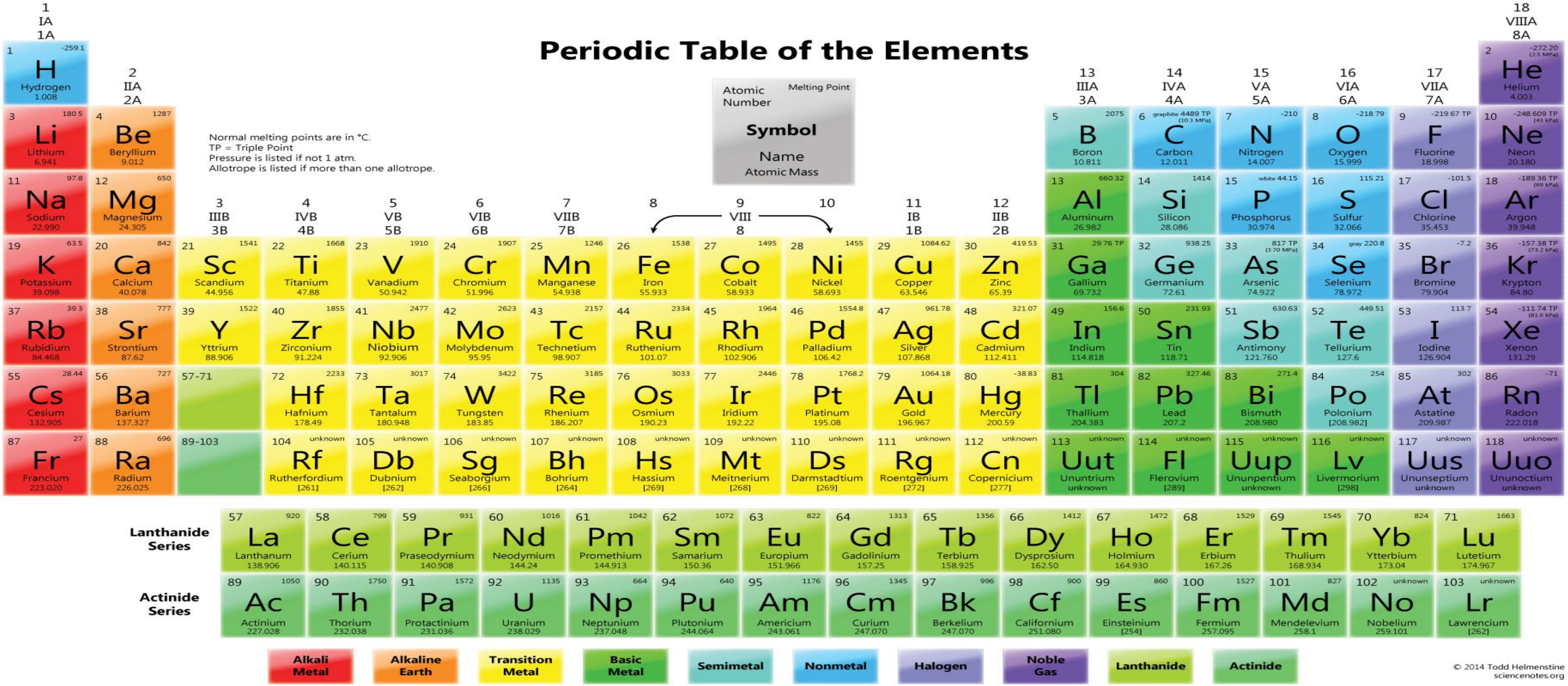
Electron Configuration: The electron configuration is $1s^2$ $2s^2$ $2p^6$, indicating a complete outer shell, which contributes to its chemical inertness.

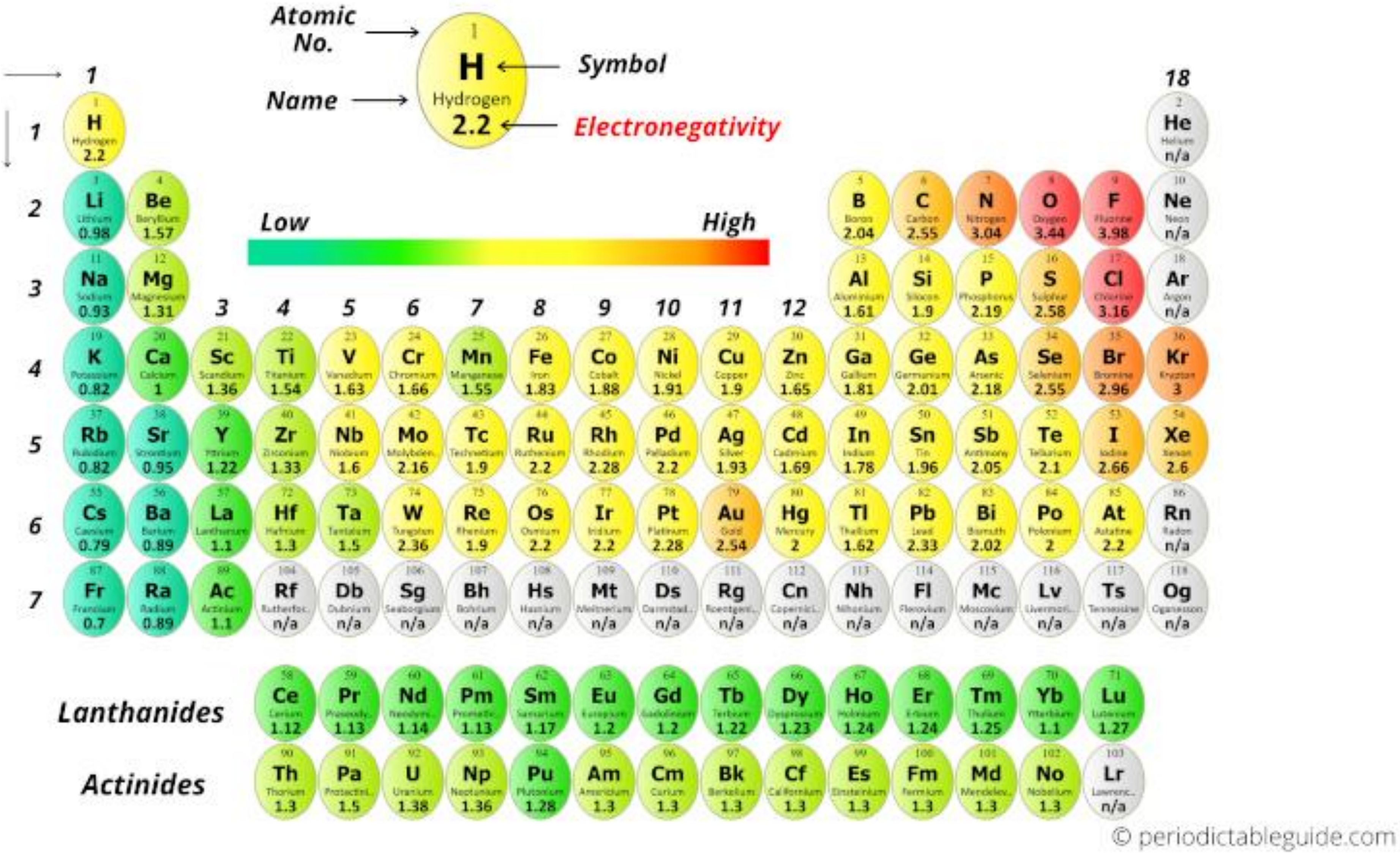
Table 1.1 Structural and electronic properties (from Beaudry and Gschneidner 1978)

Element		Z	A	Electron Config	Radius / pm Ionic	Radius / pm Metallic	Crystal Structure	Lattice Parameters 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





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)**

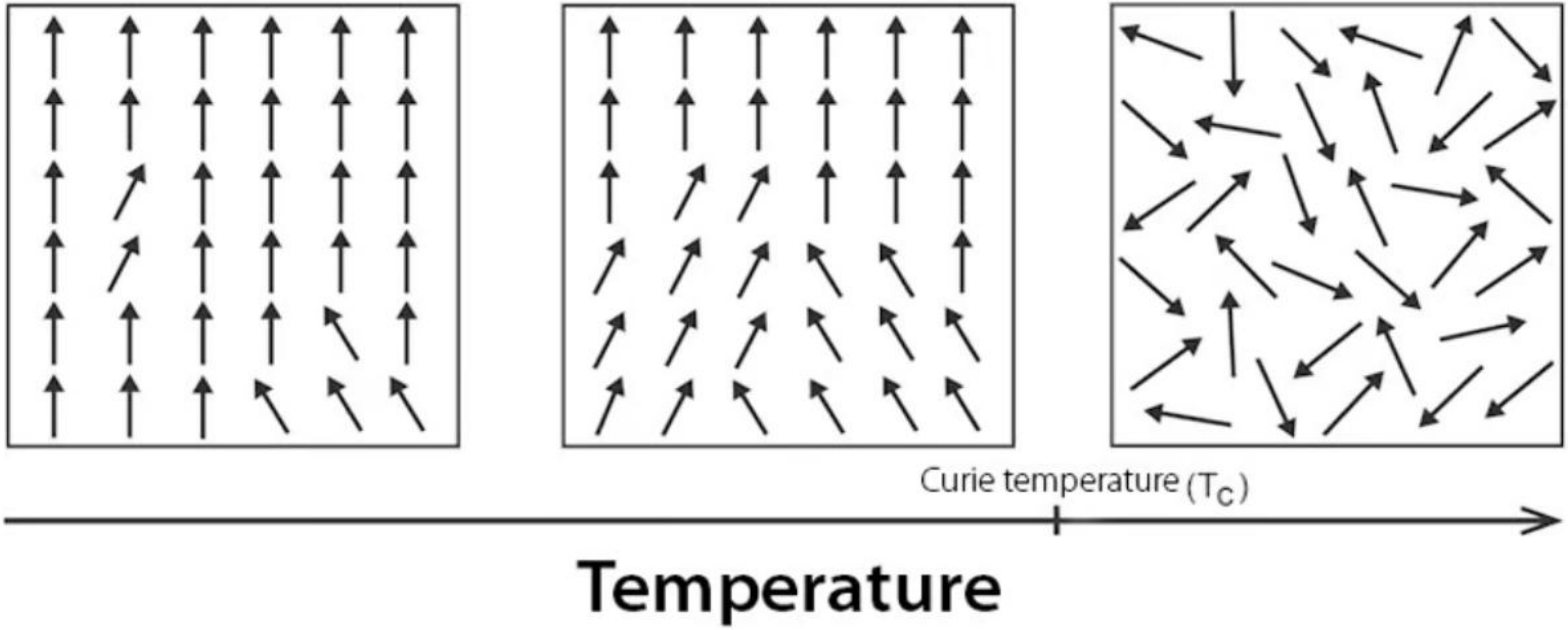
Rare Earths have different properties

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 ($Nd_2Fe_{14}B$) 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.

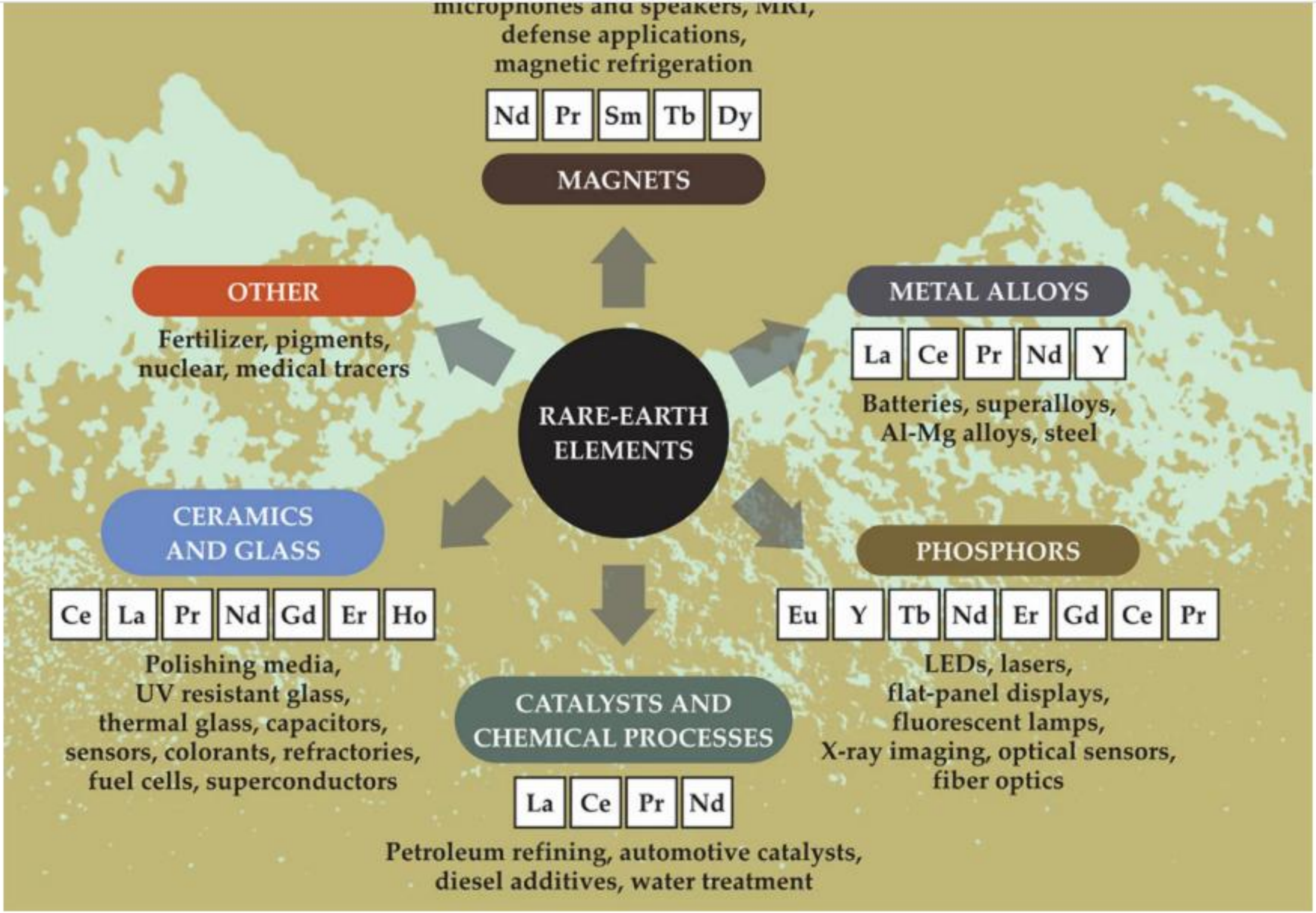
Solubility

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