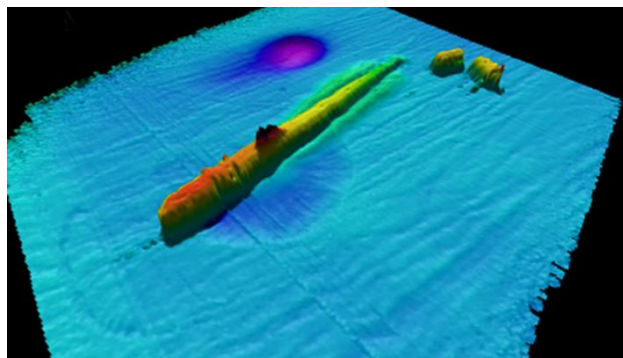
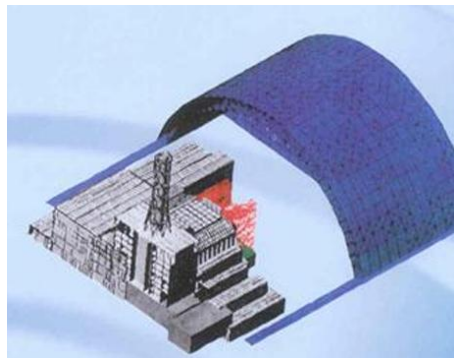
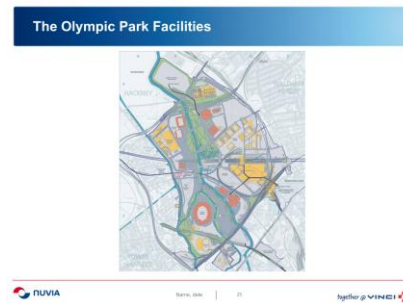
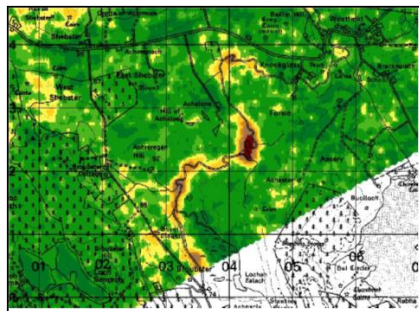


Me

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





A close-up photograph showing a person's hand, wearing a watch, holding a small gold bar. The hand is positioned over a large number of similar gold bars arranged in rows on a surface. The bars are shiny and have some markings on them.



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

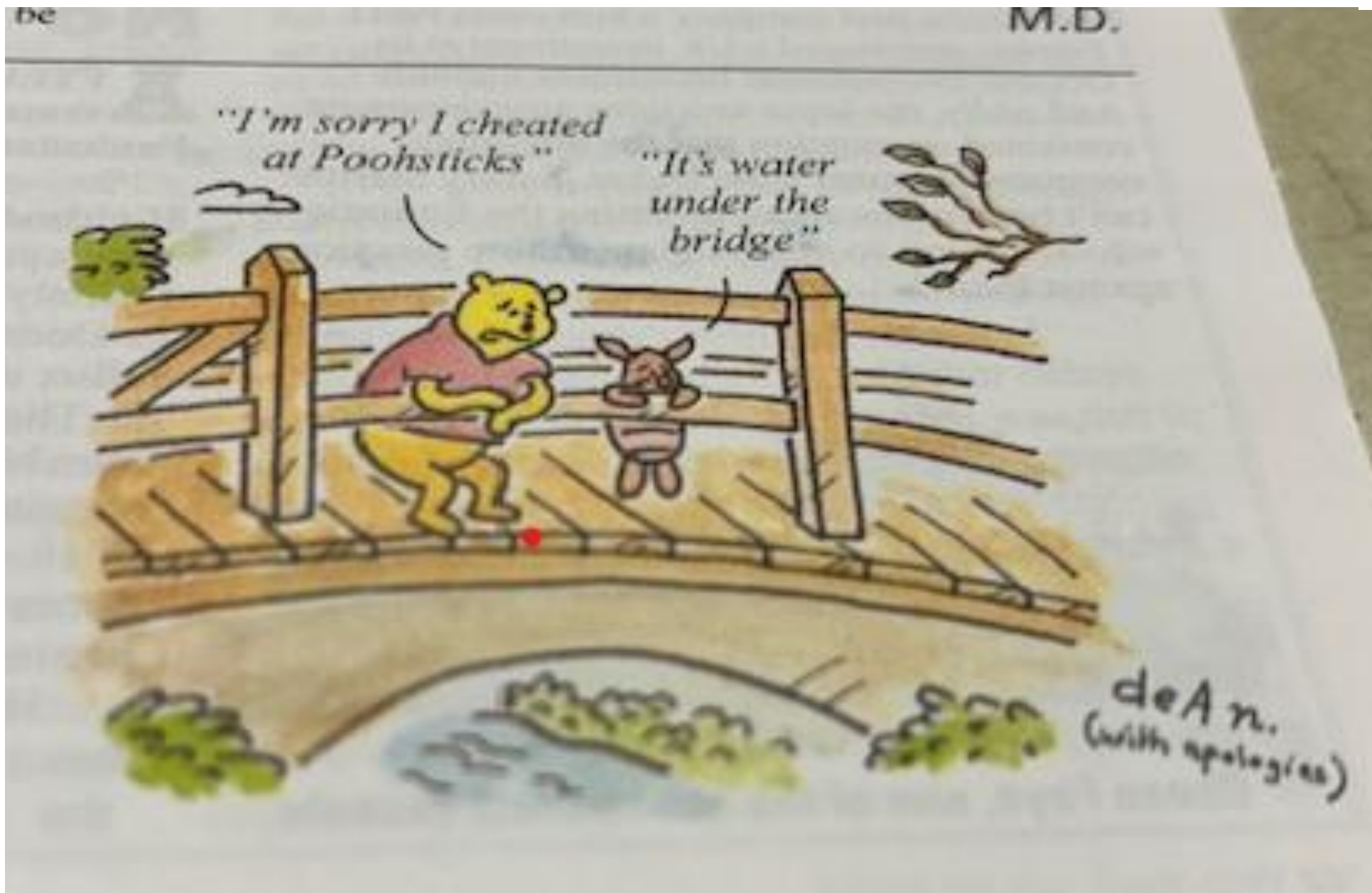
2nd June - Janet High – NHS screening – should more cancers be included?

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



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







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





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

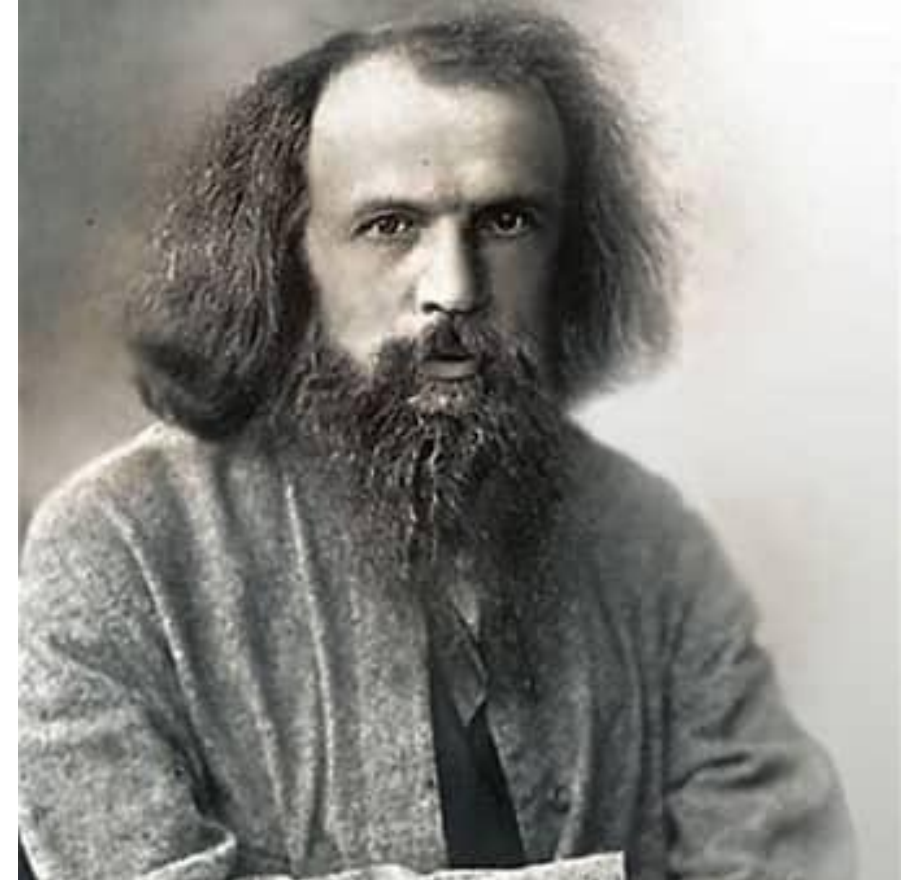
An element can be essentially defined as an atom with a nucleus that contain a specific number of protons – and thus the same number of atomic electrons

Hydrogen 1, Helium 2, Iron 26 etc

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

I		II	III	IV	V	VI	VII			
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				
								VIII		
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

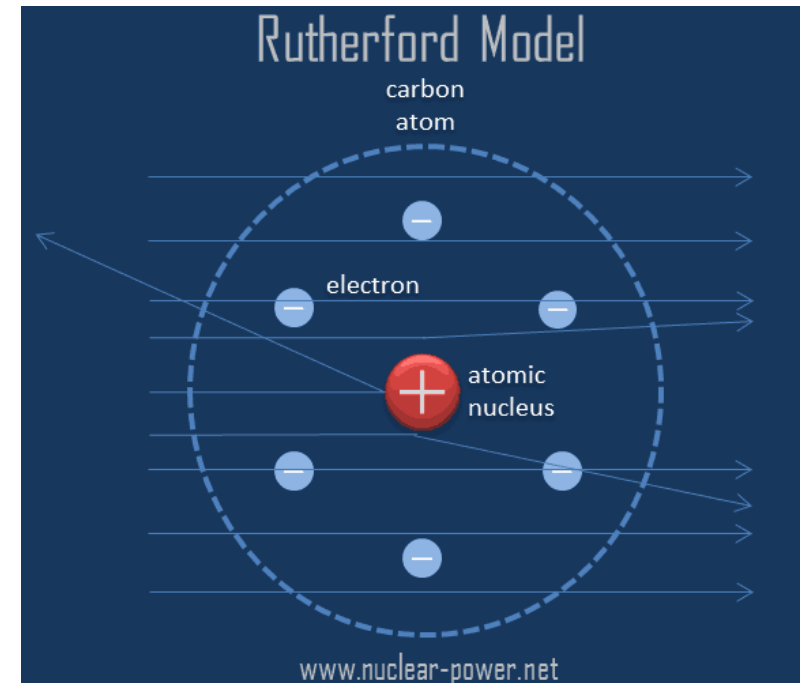
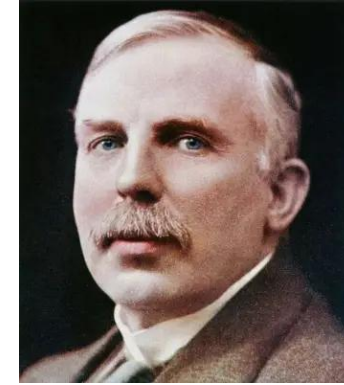
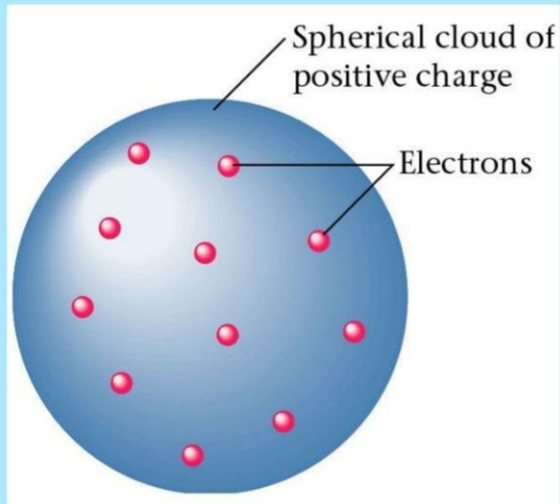


Group	I	II	III	IV	V	VI	VII	VIII
Periods	A B	A B	A B	A B	A B	A B	A B	Transition Series
Oxides:	R ₂ O	RO	R ₂ O ₃	RO ₂	R ₂ O ₅	RO ₃	R ₂ O ₇	RO ₄
Hydride :	RH	RH ₄	RH ₄	RH ₄	RH ₃	RH ₂	RH	
1.	H 1.008							
2.	Li 6.939	Be 9.012	B 10.81	C 12.011	N 14.007	O 15.999	F 18.998	
3.	Na 22.99	Mg 22.99	Al 24.31	Si 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	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 101.07 Rh 102.91 Pd 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 190.2 Rh 192.2 Pd 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



Plum Pudding model of an atom.

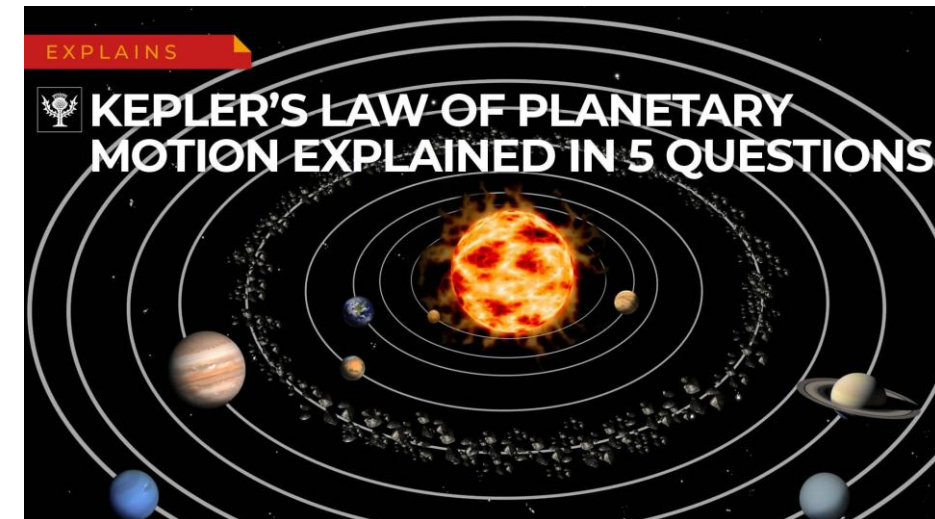
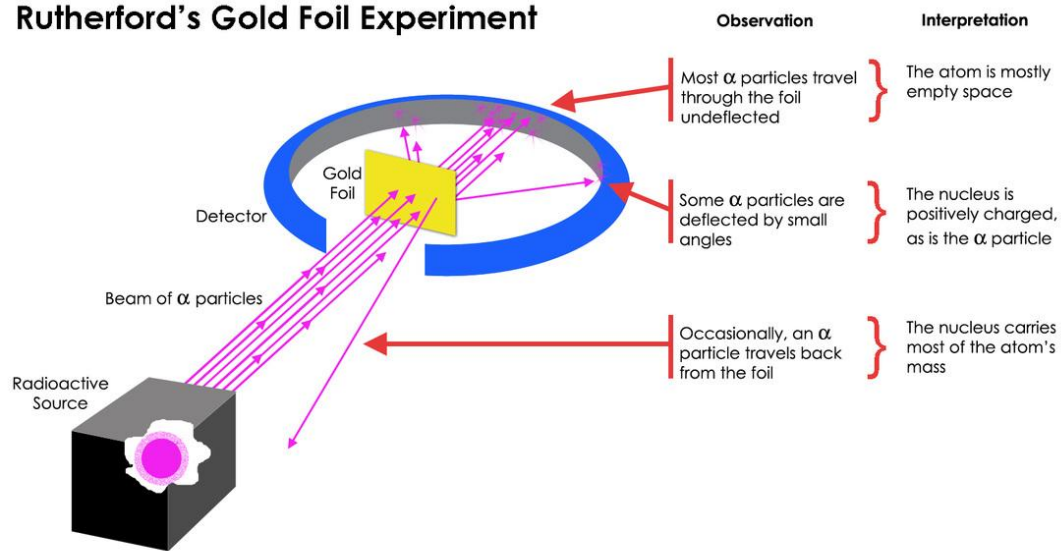


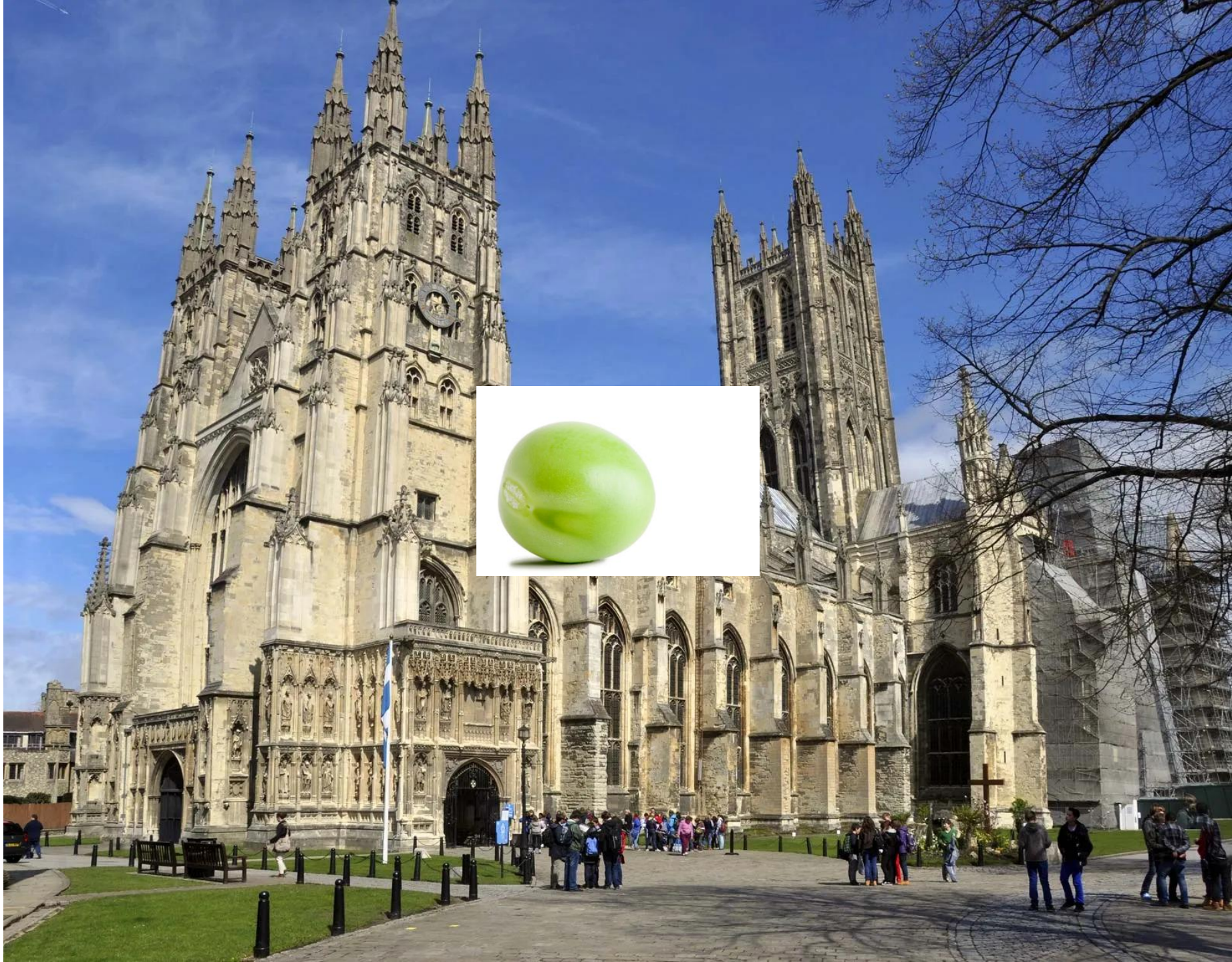
It actually took Rutherford some time to come to terms with his experiment that showed there was a nucleus in an atom.

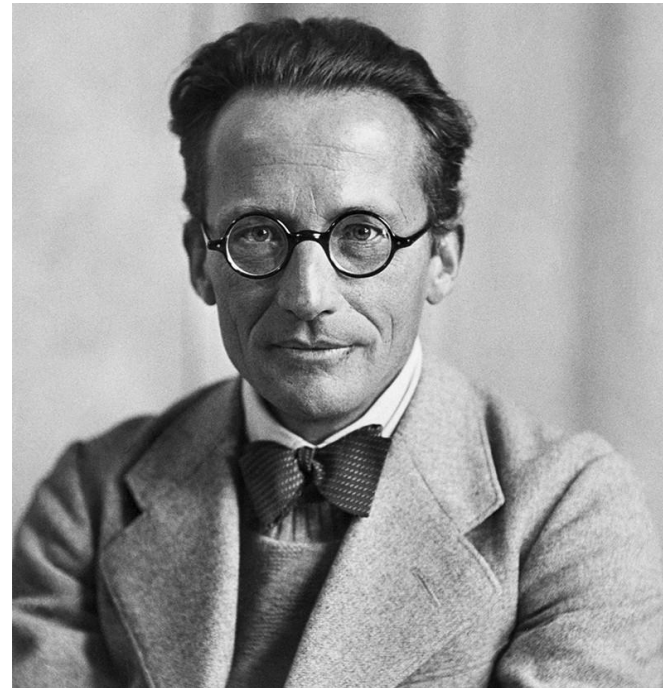
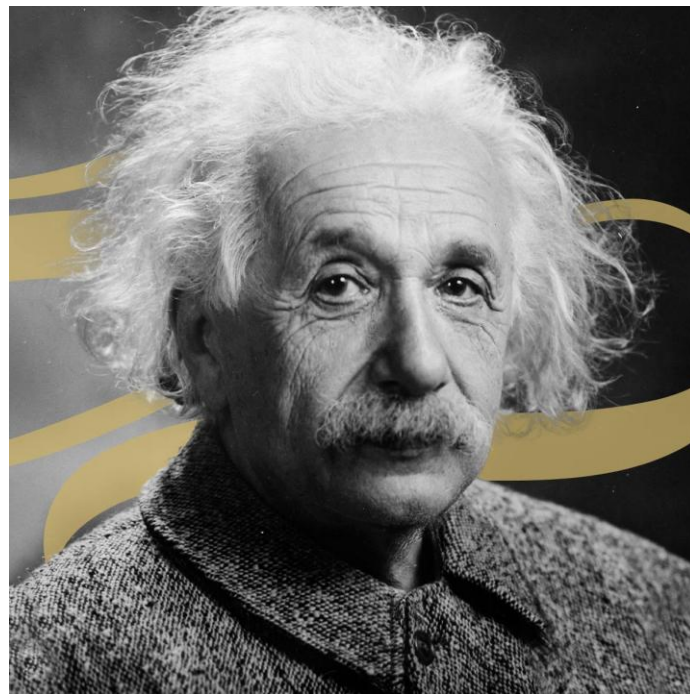
The experiment led to the rise of quantum mechanics and the 'strong force'.

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

1

IA

1A

1

H

Hydrogen

1.008

-259.1

2

IIA

2A

2

He

Helium

4.003

-272.20 (2.5 MPa)

3

Li

Lithium

6.941

180.5

4

Be

Beryllium

9.012

1287

11

Na

Sodium

22.990

97.8

12

Mg

Magnesium

24.305

650

19

K

Potassium

39.098

63.5

20

Ca

Calcium

40.078

842

37

Rb

Rubidium

84.468

39.3

38

Sr

Strontium

87.62

777

55

Cs

Cesium

132.905

28.44

56

Ba

Barium

137.327

727

87

Fr

Francium

223.020

27

88

Ra

Radium

226.025

696

21

Sc

Scandium

44.956

1541

22

Ti

Titanium

47.88

1668

23

V

Vanadium

50.942

1910

24

Cr

Chromium

51.996

1907

25

Mn

Manganese

54.938

1246

26

Fe

Iron

55.933

1538

27

Co

Cobalt

58.933

1495

28

Ni

Nickel

58.693

1455

29

Cu

Copper

63.546

1084.62

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)

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 (81.6 kPa)

57-71

Lanthanide Series

72

Hf

Hafnium

178.49

2233

73

Ta

Tantalum

180.948

3017

74

W

Tungsten

186.207

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

89-103

Actinide Series

104

Rf

Rutherfordium

[261]

105

Db

Dubnium

[262]

106

Sg

Seaborgium

[266]

107

Bh

Bohrium

[264]

108

Hs

Hassium

[269]

109

Mt

Meitnerium

[268]

110

Ds

Darmstadtium

[269]

111

Rg

Roentgenium

[272]

112

Cn

Copernicium

[277]

113

Uut

Ununtrium

unknown

114

Fl

Flerovium

[289]

115

Uup

Ununpentium

unknown

116

Lv

Livermorium

[298]

117

Uus

Ununseptium

unknown

118

Uuo

Ununoctium

unknown

141

La

Lanthanum

138.906

920

142

Ce

Cerium

140.115

799

143

Pr

Praseodymium

140.908

931

144

Nd

Neodymium

144.24

1016

145

Pm

Promethium

144.913

1042

146

Sm

Samarium

150.36

1072

147

Eu

Europium

151.966

822

148

Gd

Gadolinium

157.25

1313

149

Tb

Terbium

158.925

1356

150

Dy

Dysprosium

162.50

1412

151

Ho

Holmium

164.930

1472

152

Er

Erbium

167.26

1529

153

Tm

Thulium

168.934

1545

154

Yb

Ytterbium

173.04

824

155

Lu

Lutetium

174.967

1663

156

Ac

Actinium

227.028

1050

157

Th

Thorium

232.038

1750

158

Pa

Protactinium

231.036

1572

159

U

Uranium

238.029

1135

160

Np

Neptunium

237.048

664

161

Pu

Plutonium

244.064

640

162

Am

Americium

243.061

1176

163

Cm

Curium

247.070

1345

164

Bk

Berkelium

247.070

996

165

Cf

Californium

251.080

900

166

Es

Einsteinium

[254]

860

167

Fm

Fermium

257.095

1527

168

Md

Mendelevium

258.1

827

169

No

Nobelium

259.101

unknown

170

Lr

Lawrencium

[262]

unknown

Alkali Metal

Alkaline Earth

Transition Metal

Basic Metal

Semimetal

Nonmetal

Halogen

Noble Gas

Lanthanide

Actinide

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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.

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

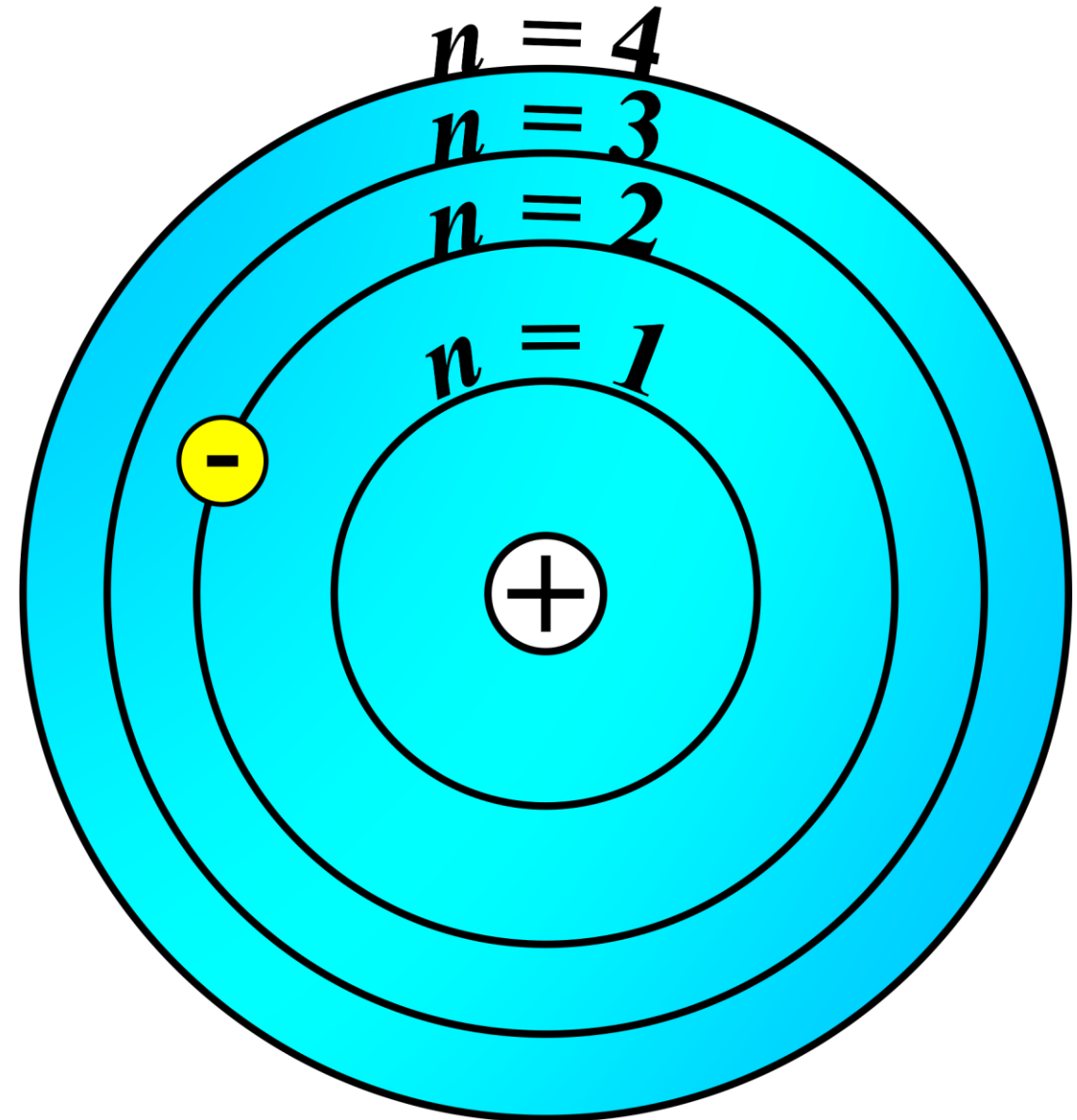
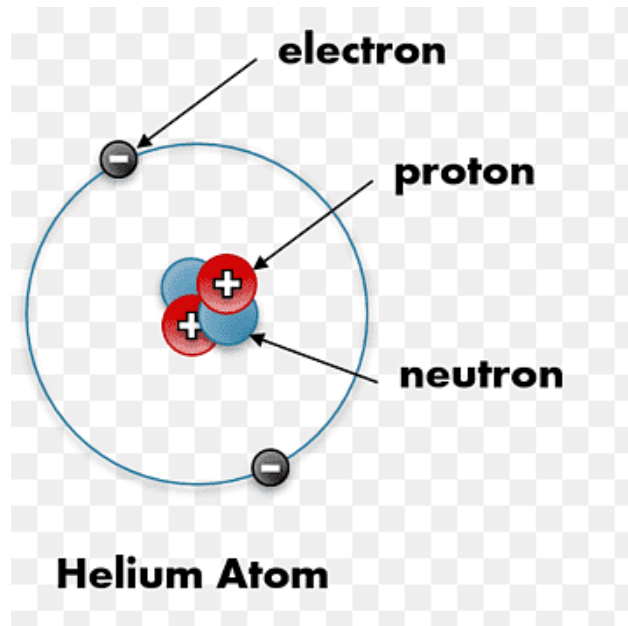
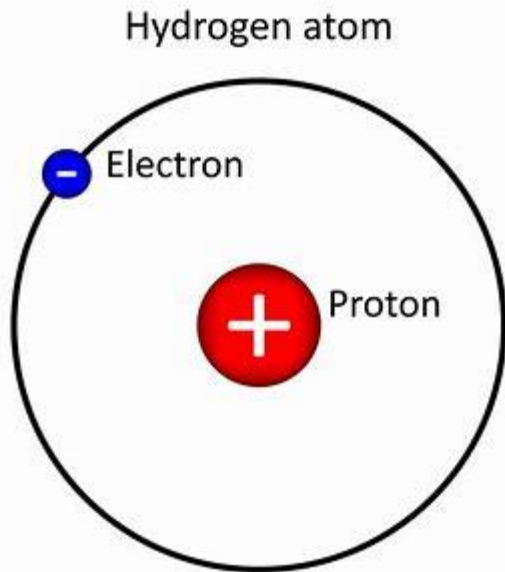
Ce 58	Pr 59	Nd 60	Pm 61	Sm 62	Eu 63	Gd 64	Tb 65	Dy 66	Ho 67	Er 68	Tm 69	Yb 70	Lu 71
Th 90	Pa 91	U 92	Np 93	Pu 94	Am 95	Cm 96	Bk 97	Cf 98	Es 99	Fm 100	Md 101	No 102	Lr 103

$$n : 4 \rightarrow 2$$

K, L, M

s, p, d, e, f

Quantum mechanics $2n^2$



So, what exactly is going on?

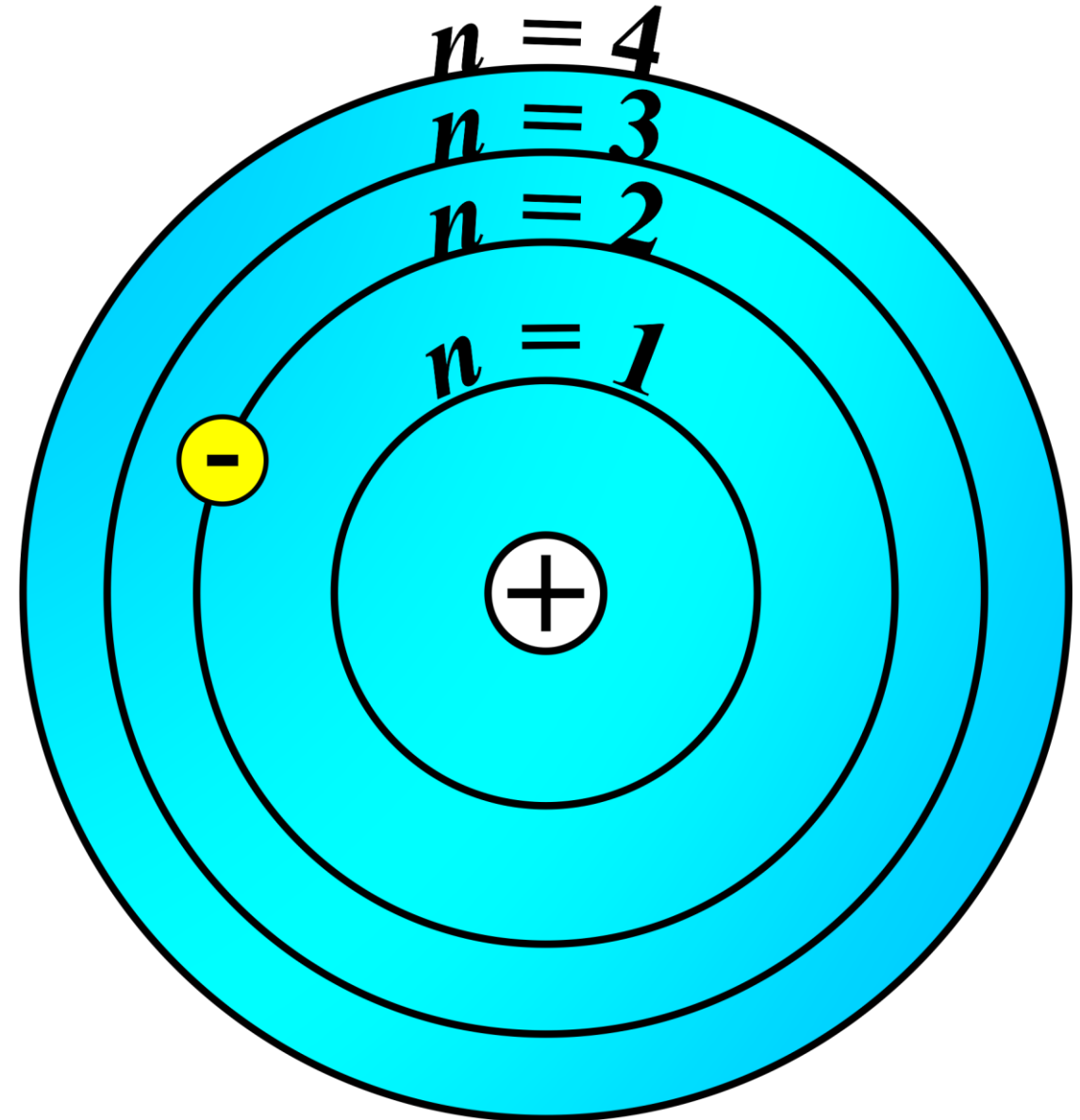
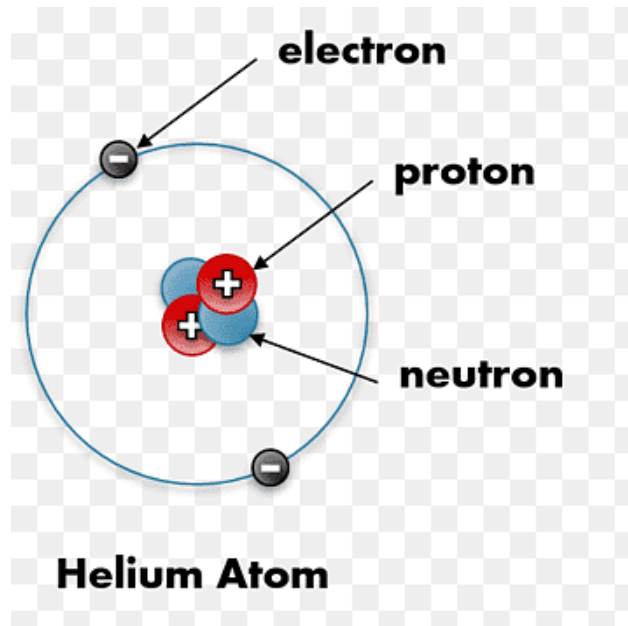
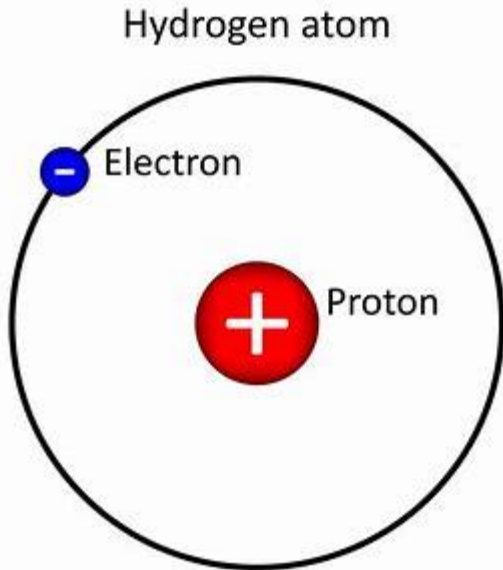


$$n : 4 \rightarrow 2$$

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.

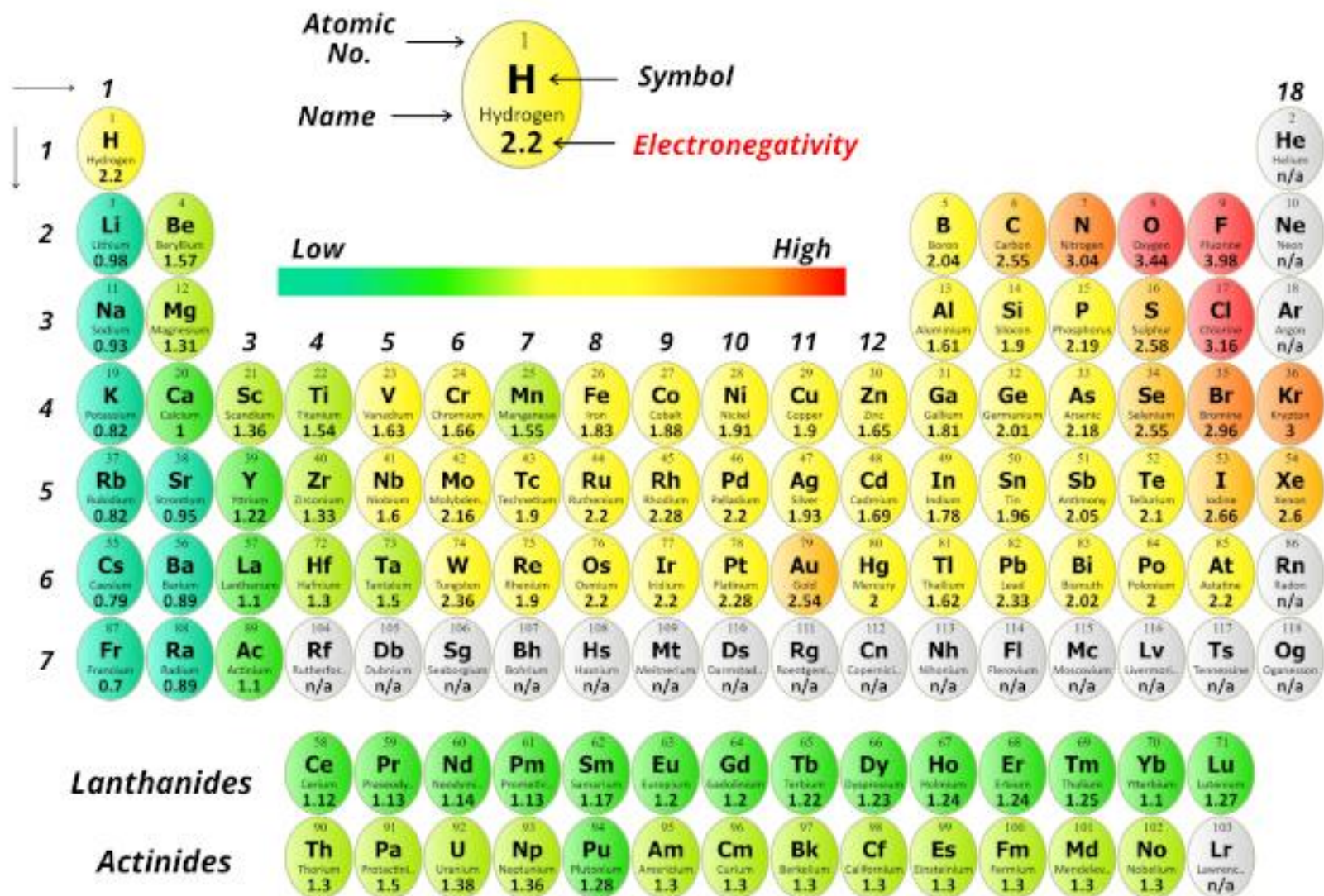
Electron Configuration: The electron configuration is $1s^2 2s^2 2p^6$, indicating a complete outer shell, which contributes to its chemical inertness.

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

Element		Z	A	Electron	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	rhomb	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

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

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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)**

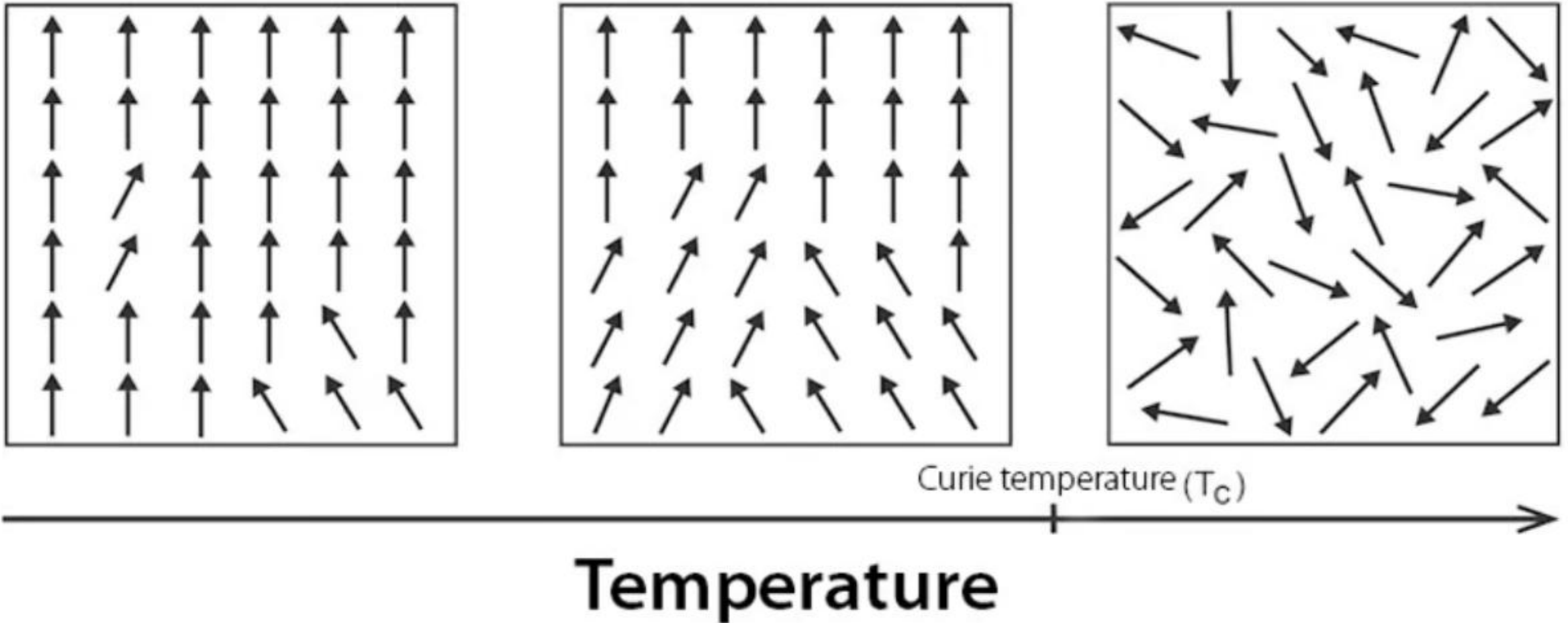
Rare Earths have different properties

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.

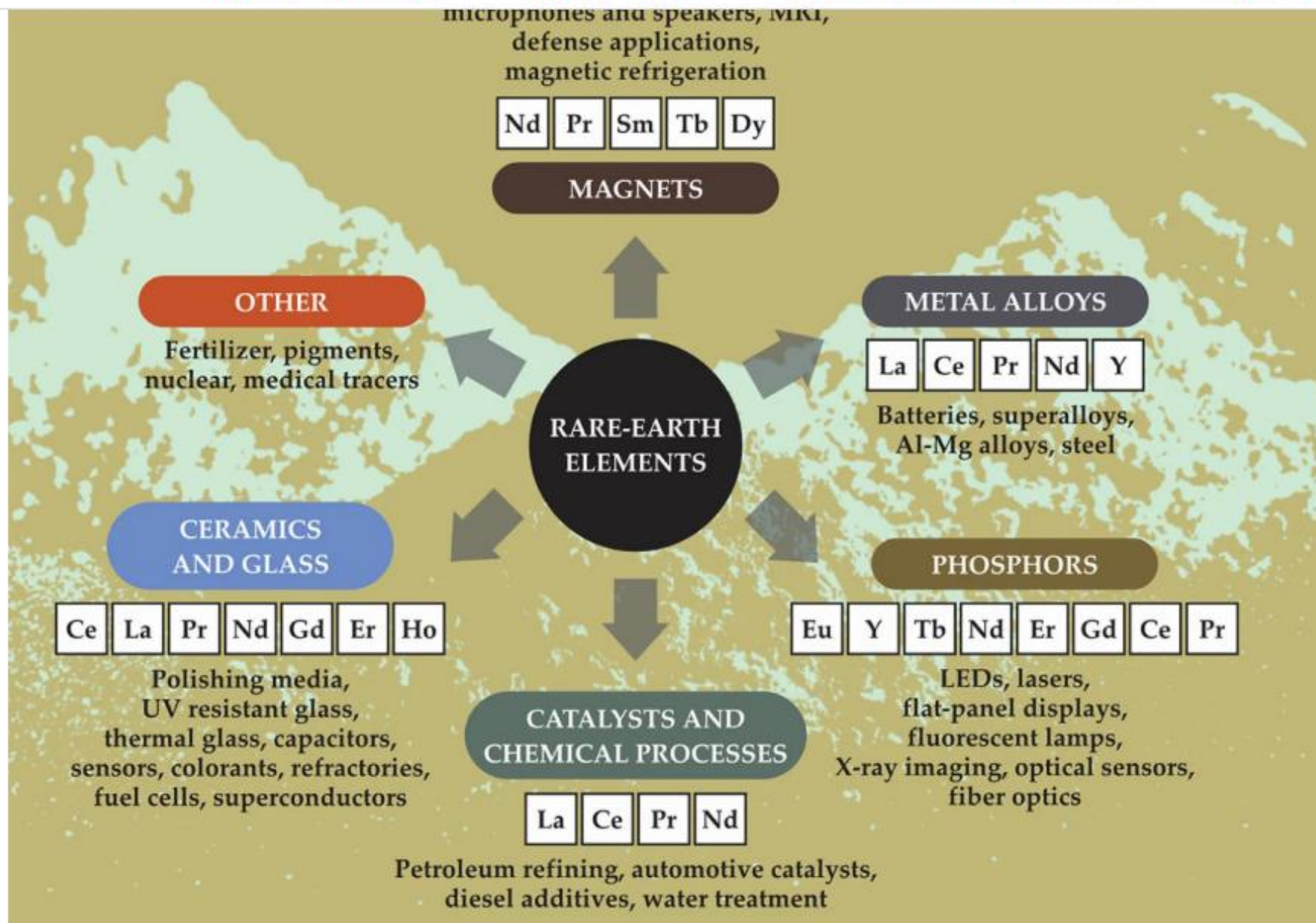
Solubility

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

