原子核で周期表を作ってみたら
:エレメンタッチからニュークリタッチへ
A nuclear periodic table
: from elementouch to nucletouch

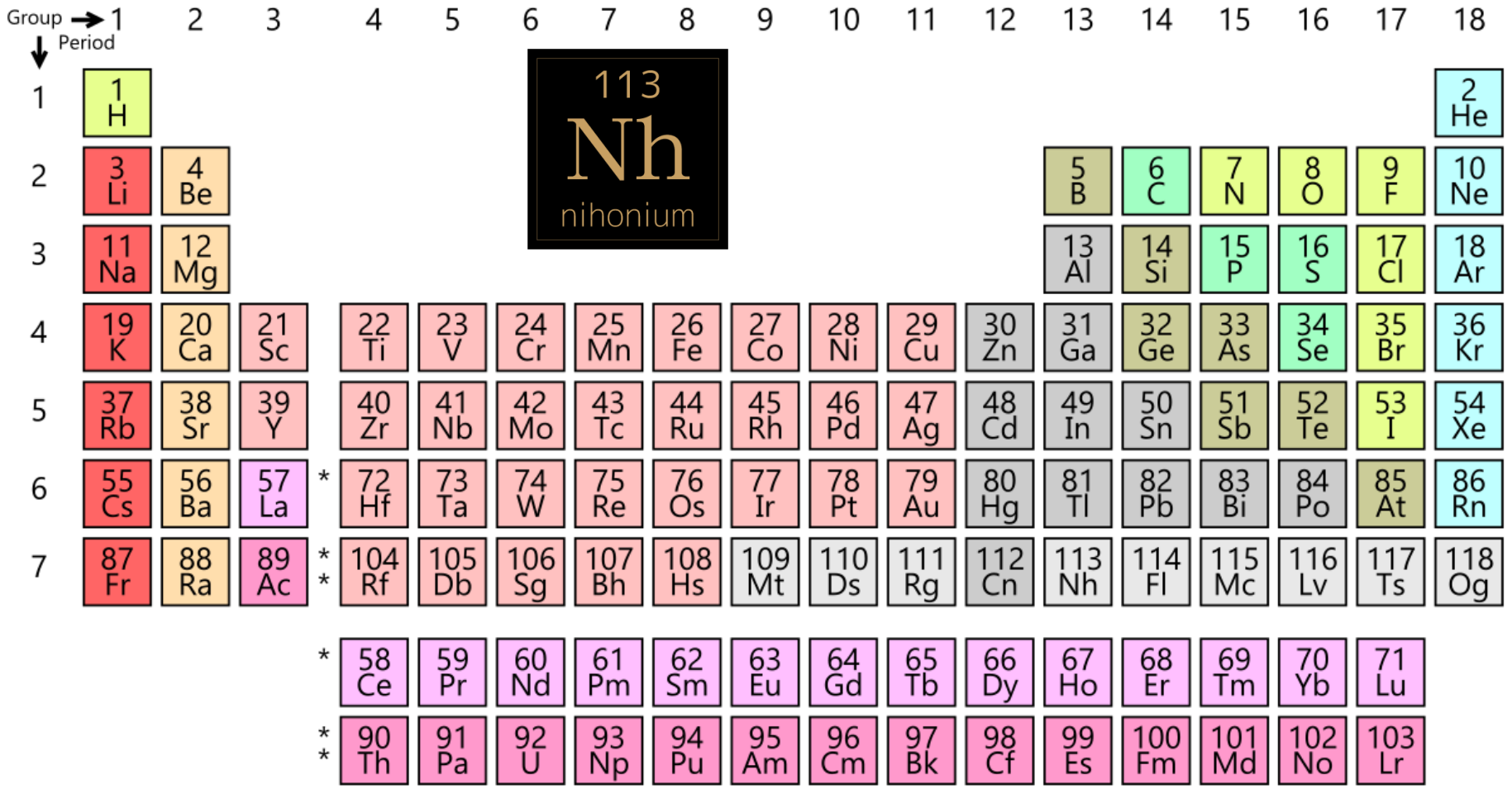
Kouichi Hagino
Yoshiteru Maeno
Kyoto University

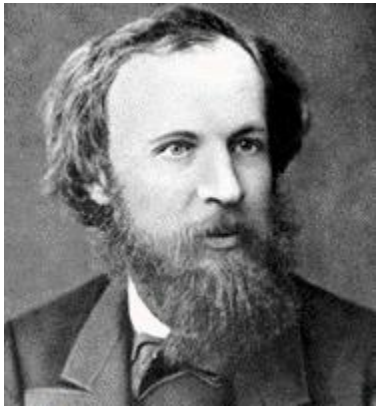
International Year
of the Periodic Table
of Chemical Elements

1. Introduction: periodic table
2. Nuclear periodic table
3. A *magic* coincidence
4. Summary

核データ研究会　2021.11.18-19, online

Introduction: periodic table of elements

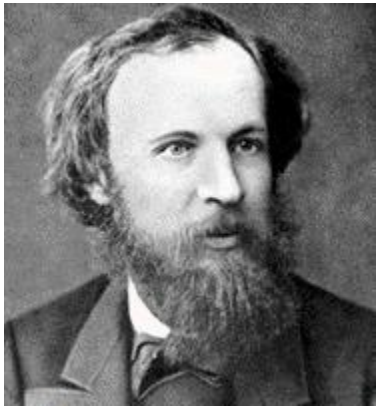




the original periodic table by Mendeleev (1869)

Ann. Suppl. **8**, 133 (1871).

Reihen	Gruppe 1 — R_2O	Gruppe 2 — RO	Gruppe 3 — R_2O_3	Gruppe 4 RH_4 RO_2	Gruppe 5 RH_3 R_2O_5	Gruppe 6 RH_2 RO_3	Gruppe 7 RH R_2O_7	Gruppe 8 — RO_4
1	H=1							
2	Li=7	Be=9.4	B=11	C=12	N=14	O=16	F=19	
3	Na=23	Mg=24	Al=27.3	Si=28	P=31	S=32	Cl=35.5	
4	K=39	Ca=40	-=44	Ti=48	V=51	Cr=52	Mn=55	Fe=56 Co=59 Ni=59 Cu=63
5	(Cu=63)	Zn=65	-=68	-=72	As=75	Se=78	Br=80	
6	Rb=85	Sr=87	?Yt=88	Zr=90	Nb=94	Mo=96	-=100	Ru=104 Rh=104 Pd=106 Ag=108
7	(Ag=108)	Cd=112	In=113	Sn=118	Sb=122	Te=125	J=127	
8	Cs=133	Ba=137	?Di=138	?Ce=140	—	—	—	— — — —
9	(—)	—	—	—	—	—	—	
10	—	—	?Er=178	?La=180	Ta=182	W=184	—	Os=195 Ir=197 Pt=198 Au=199
11	(Au=199)	Hg=200	Tl=204	Pb=207	Bi=208	—	—	
12	—	—	—	Th=231	—	U=240	—	— — — —



the original periodic table by Mendeleev

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Predictions of unknown elements

Reihen	Gruppe 1 — R_2O	Gruppe 2 — RO	Gruppe 3 — R_2O_3	Gruppe 4 RH_4 RO_2	Gruppe 5 RH_3 R_2O_5	Gruppe 6 RH_2 RO_3	Gruppe 7 RH R_2O_7	Gruppe 8 — RO_4
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10	—	—	?Er=178	?La=180	Ta=182	W=184	—	Os=195 Ir=197 Pt=198 Au=199
11	(Au=199)	Hg=200	Tl=204	Pb=207	Bi=208	—	—	
12	—	—	—	Th=231	—	U=240	—	— — — —

a discovery of Galium (1874)

a discovery of Germanium (1879)

Who invented the periodic table in the present form (the long form)?

Y. Maeno, K. Hagino, and T. Ishiguro,
Found. of Chem. 23, 201 (2021)

1	1 H																2 He
2	3 Li	4 Be											5 B	6 C	7 N	8 O	9 F	10 Ne
3	11 Na	12 Mg											13 Al	14 Si	15 P	16 S	17 Cl	18 Ar
4	19 K	20 Ca	21 Sc	22 Ti	23 V	24 Cr	25 Mn	26 Fe	27 Co	28 Ni	29 Cu	30 Zn	31 Ga	32 Ge	33 As	34 Se	35 Br	36 Kr
5	37 Rb	38 Sr	39 Y	40 Zr	41 Nb	42 Mo	43 Tc	44 Ru	45 Rh	46 Pd	47 Ag	48 Cd	49 In	50 Sn	51 Sb	52 Te	53 I	54 Xe
6	55 Cs	56 Ba	57 La	* 72 Hf	73 Ta	74 W	75 Re	76 Os	77 Ir	78 Pt	79 Au	80 Hg	81 Tl	82 Pb	83 Bi	84 Po	85 At	86 Rn
7	87 Fr	88 Ra	89 Ac	* 104 Rf	105 Db	106 Sg	107 Bh	108 Hs	109 Mt	110 Ds	111 Rg	112 Cn	113 Nh	114 Fl	115 Mc	116 Lv	117 Ts	118 Og
				* 58 Ce	59 Pr	60 Nd	61 Pm	62 Sm	63 Eu	64 Gd	65 Tb	66 Dy	67 Ho	68 Er	69 Tm	70 Yb	71 Lu	
				* 90 Th	91 Pa	92 U	93 Np	94 Pu	95 Am	96 Cm	97 Bk	98 Cf	99 Es	100 Fm	101 Md	102 No	103 Lr	

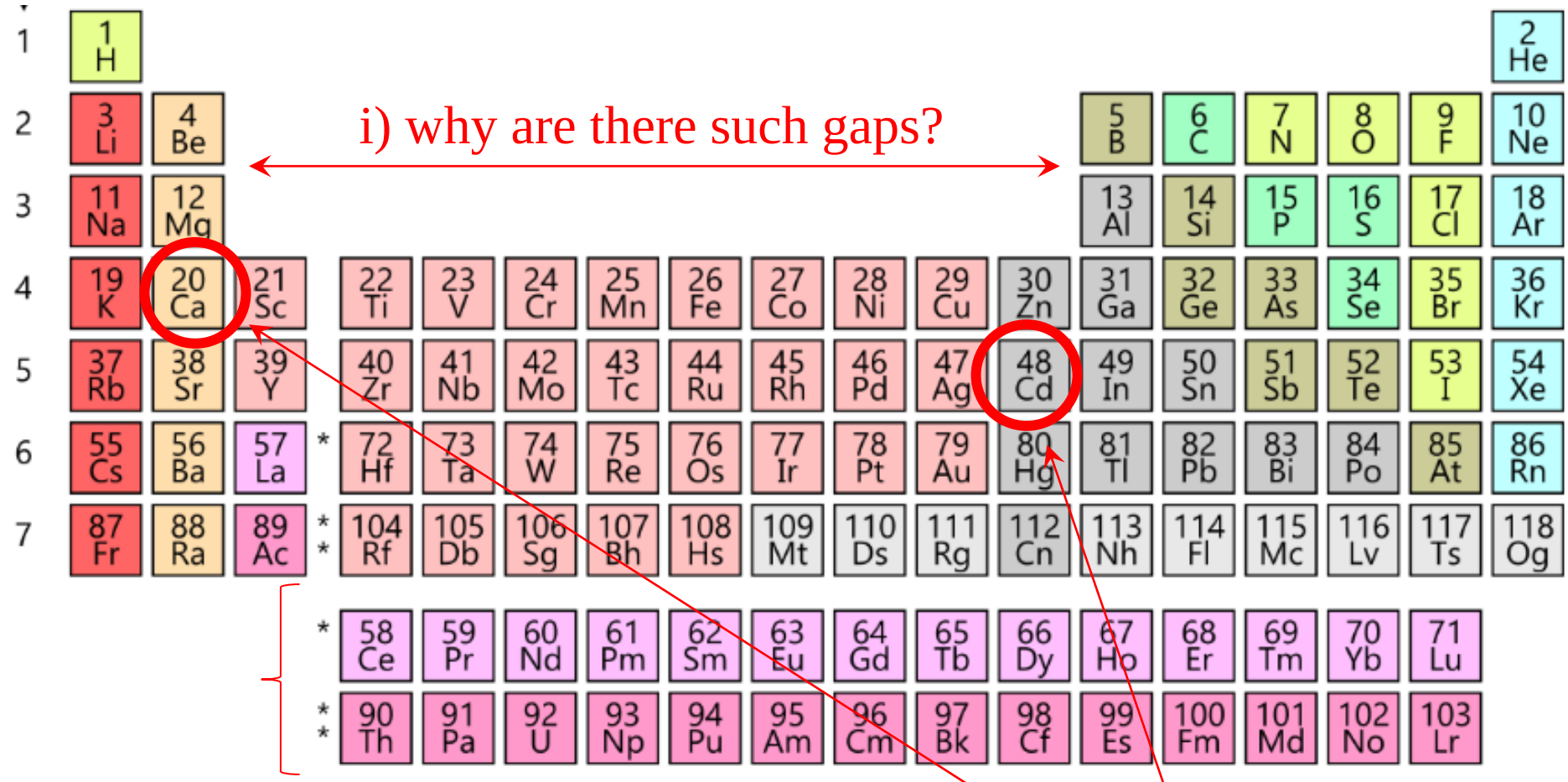
Alfred Werner (1905)

a chemist of Univ. Zurich, Switzerland

1913: the first Nobel prize in Inorganic Chenistry

（遷移元素錯体の八面体形の構造：錯体化学の創始者）

Any improvements?

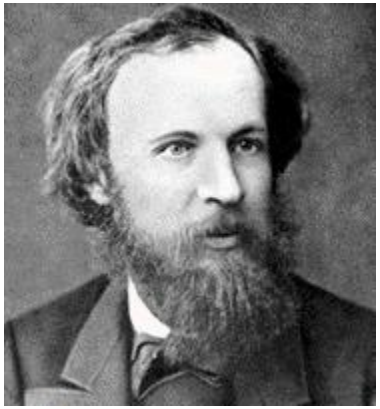


i) why are there such gaps?

ii) why in separated tables?

iii) why are similar elements separated?

another example: Ti-Sn



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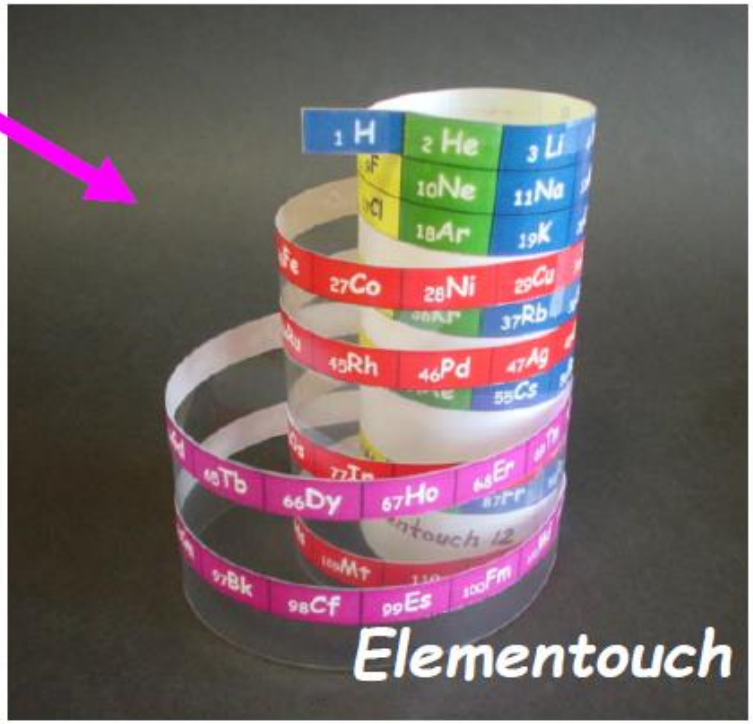
11	(Au=199)	Hg=200	Tl=204	Pb=207	Bi=208	—	—	
12	—	—	—	Th=231	—	U=240	—	— — — —

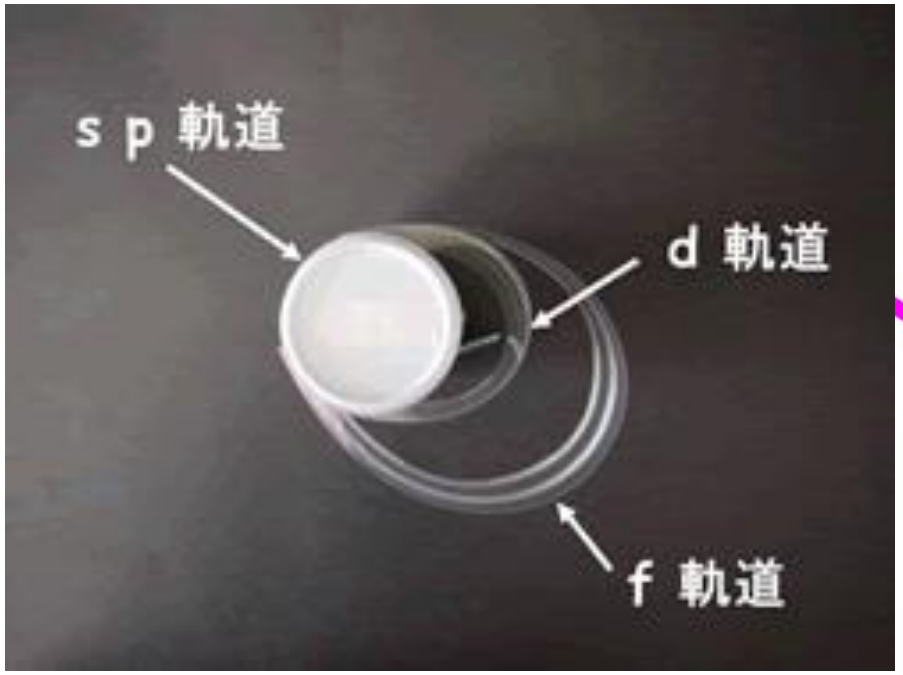
Elementouch

The three problems are all resolved !



Y. Maeno, Butsuri 57, 681 (2002) (in Japanese)
Y. Maeno, K.Hagino, T. Ishiguro,
Found. of Chem. 23, 201 (2021)

Elementouch



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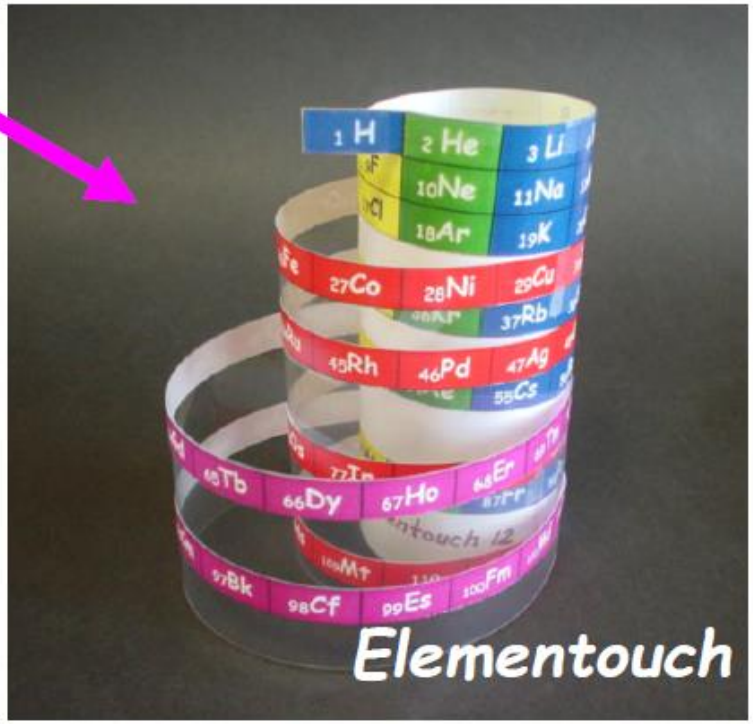

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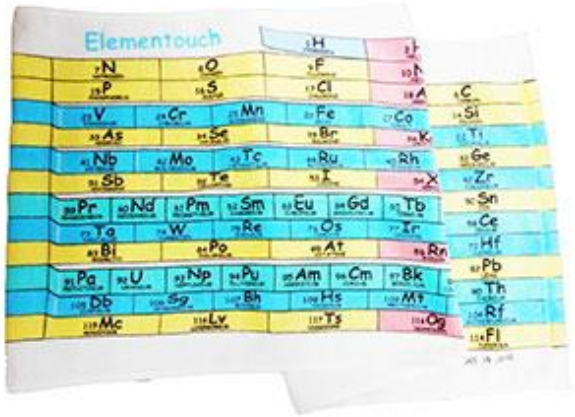
https://ss.scphys.kyoto-u.ac.jp/elementouch/images/illustration/

Quantum Materials Lab., Kyoto University

Kyoto-U. coop

pen stand

mug cup

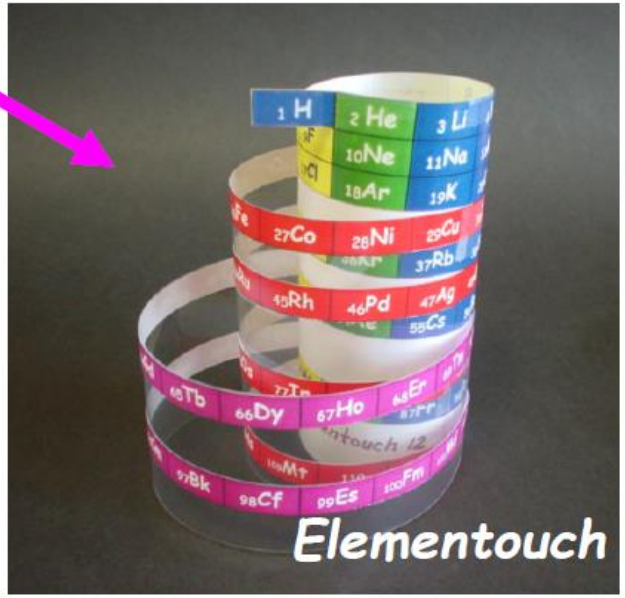


towel

T-shirt

Elementouch

The three problems are all resolved !

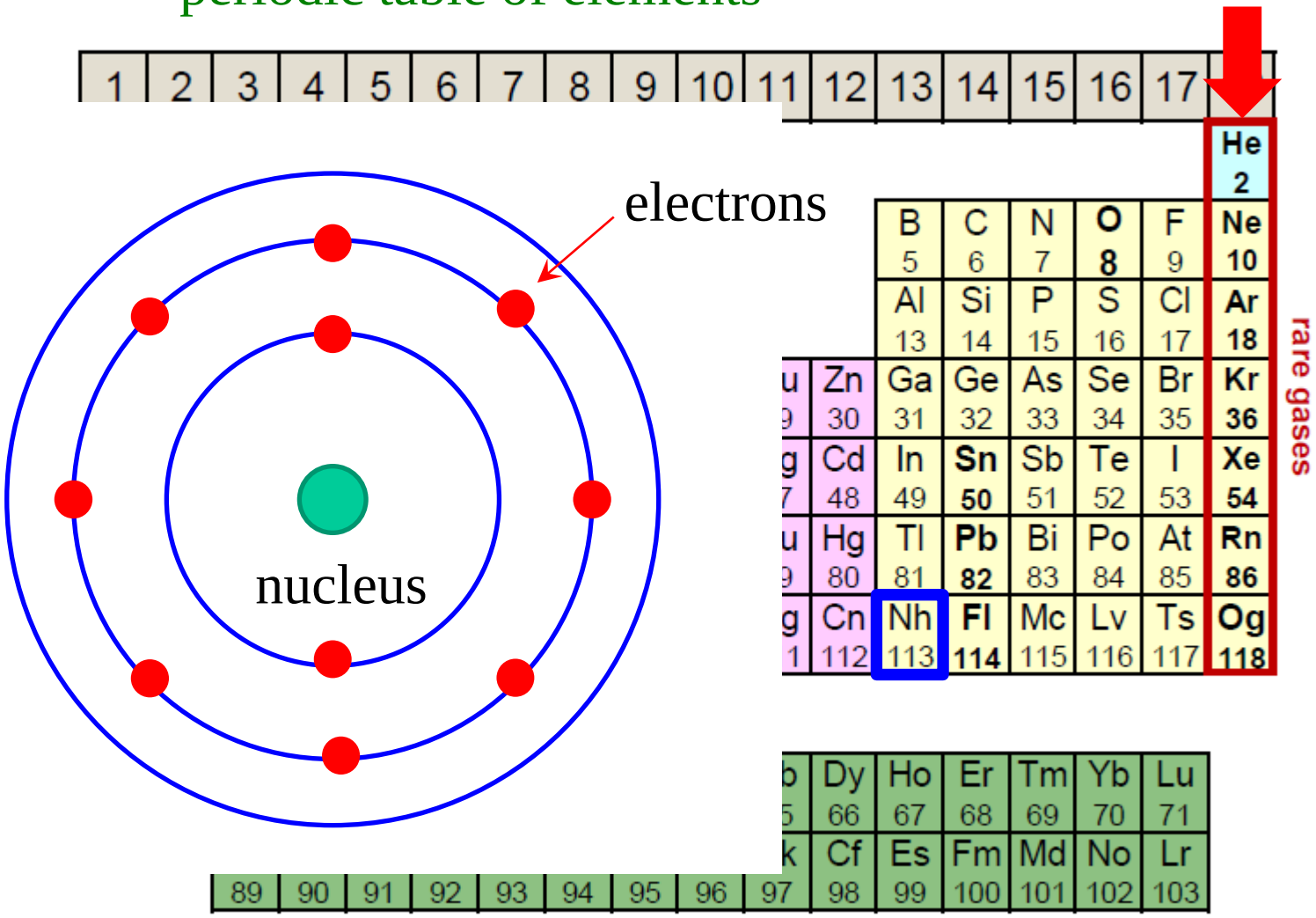


pictures from
Quantum Materials Lab.,
Kyoto University

the origin of periodicity

noble gas
(shell closures)

periodic table of elements



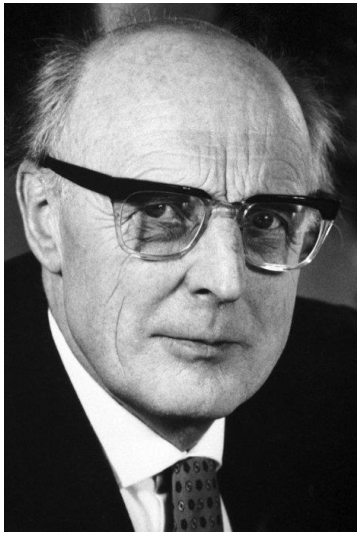
Nuclear Shell Structures

Magic Numbers

2, 8, 20, 28, 50, 82, 126

Shell Model

Mayer

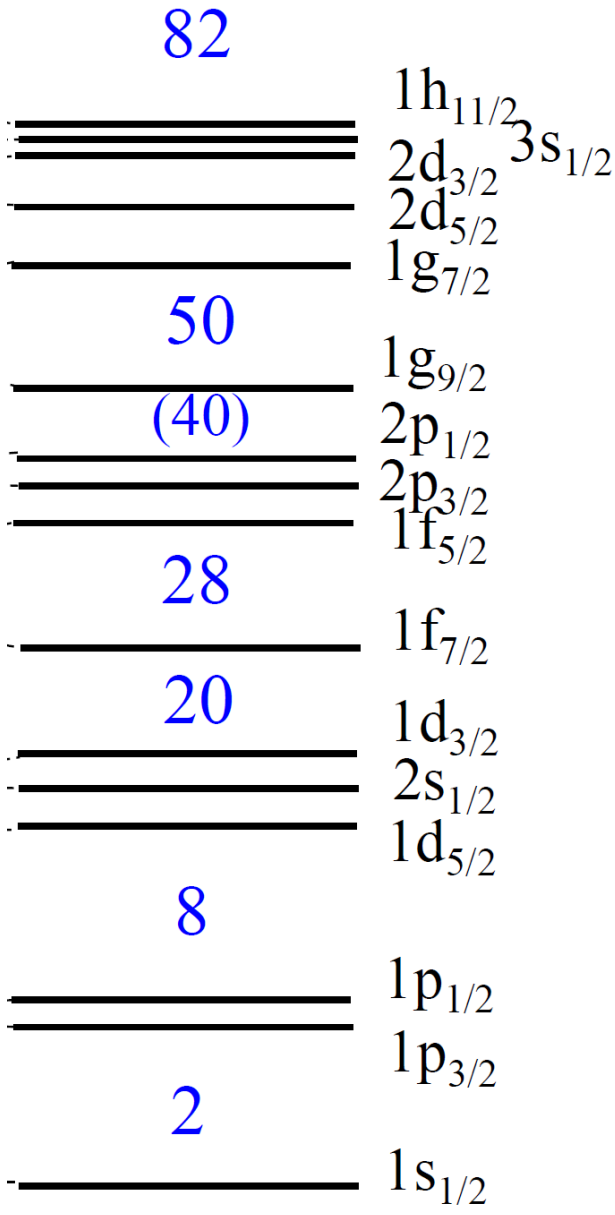


Jensen

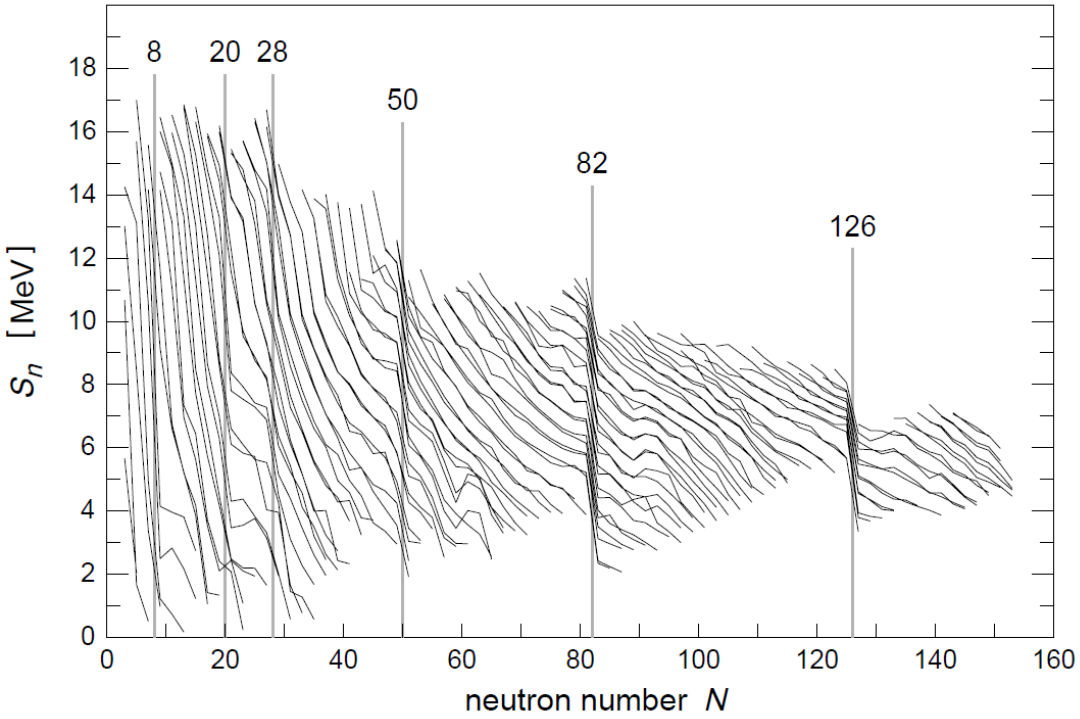
Nobel Foundation archive

Nobel prize in Physics (1963)

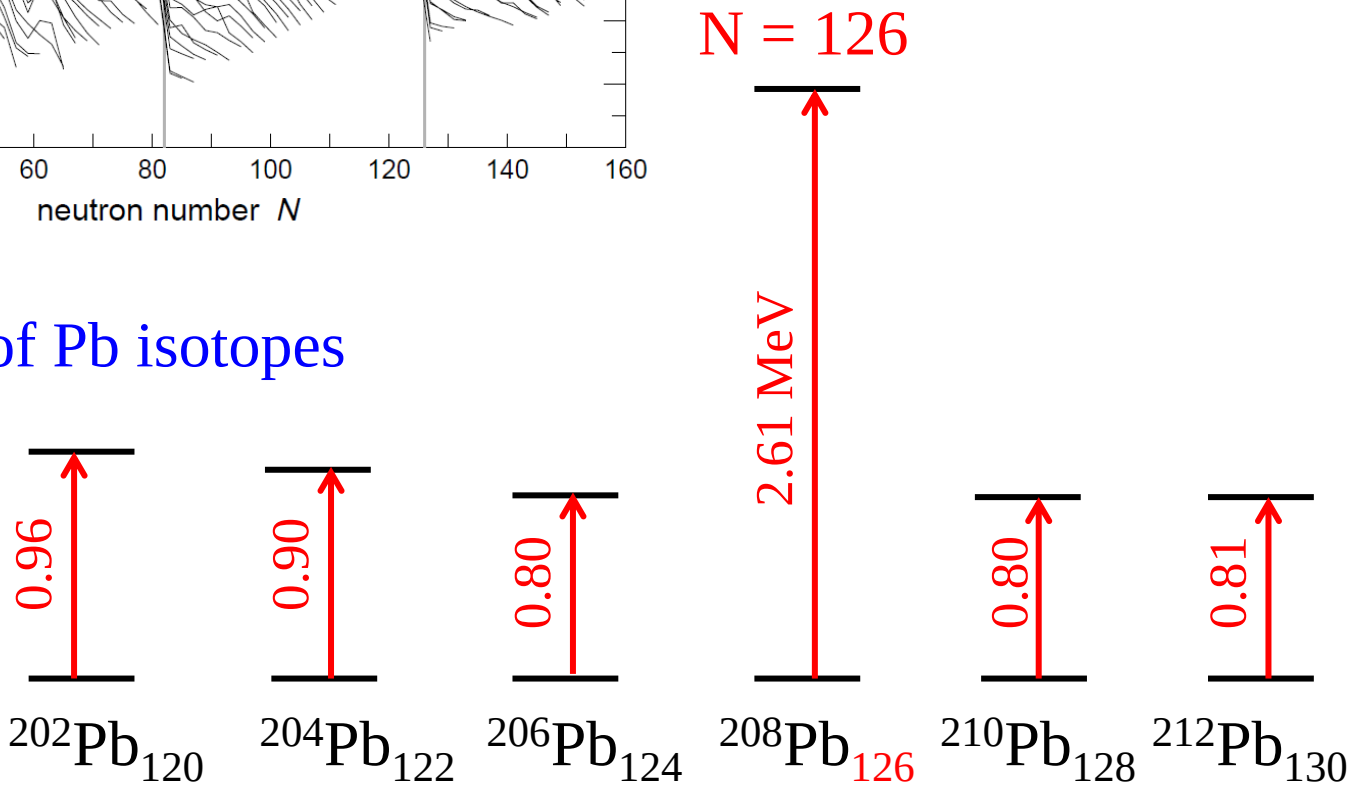
spin-orbit interaction



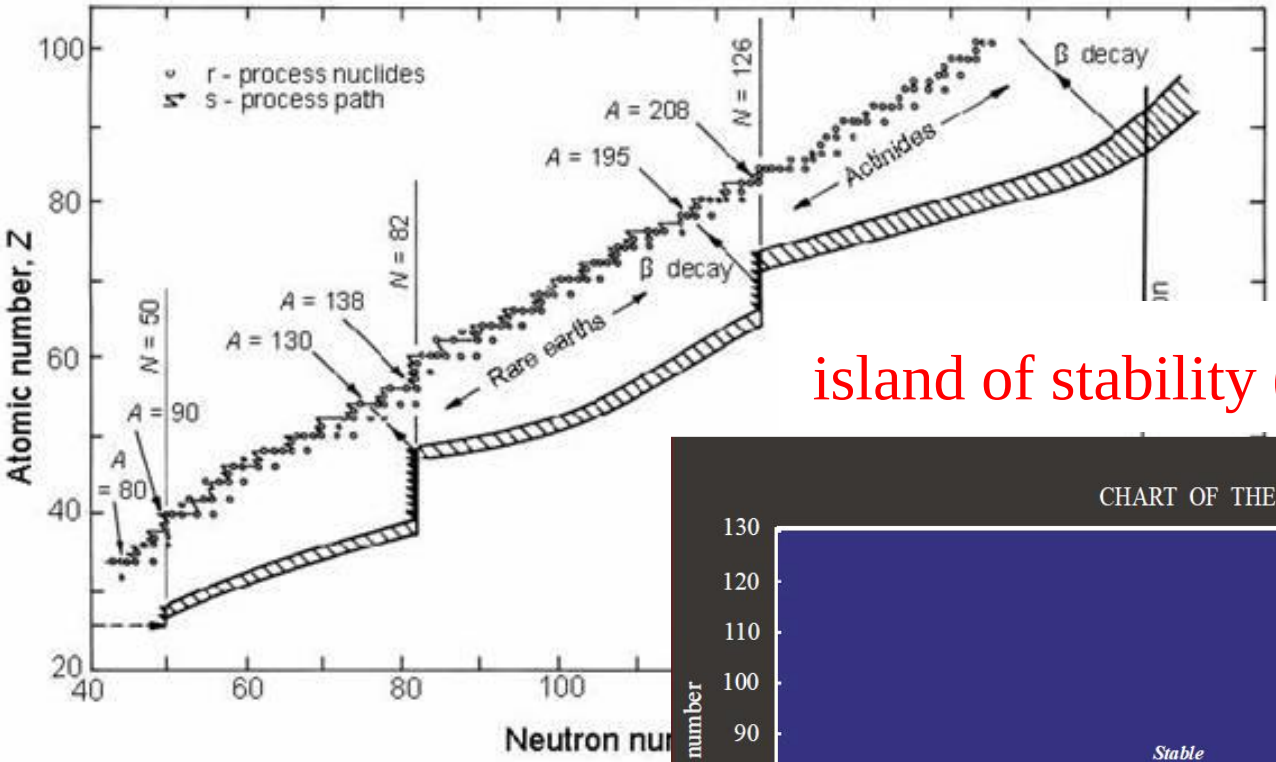
One-neutron separation energy



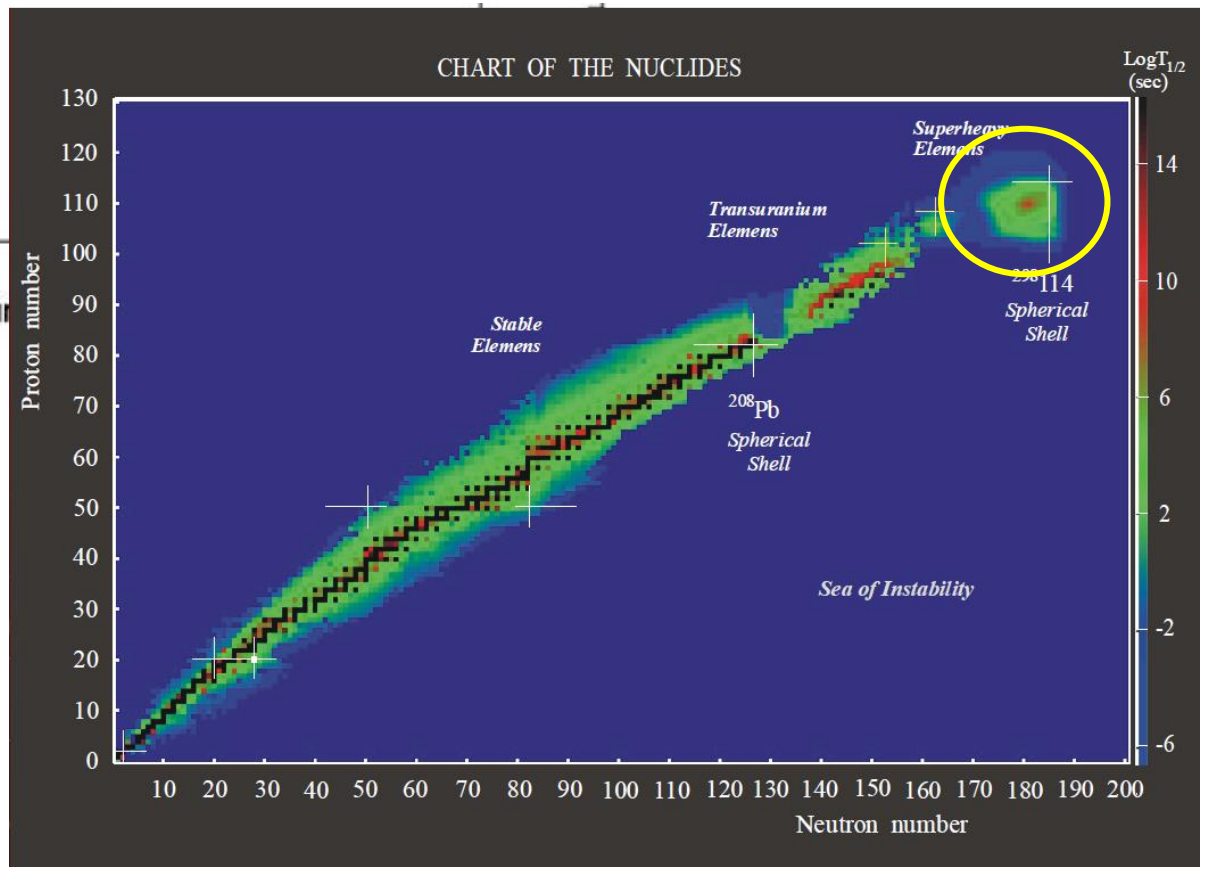
1st excited state of Pb isotopes



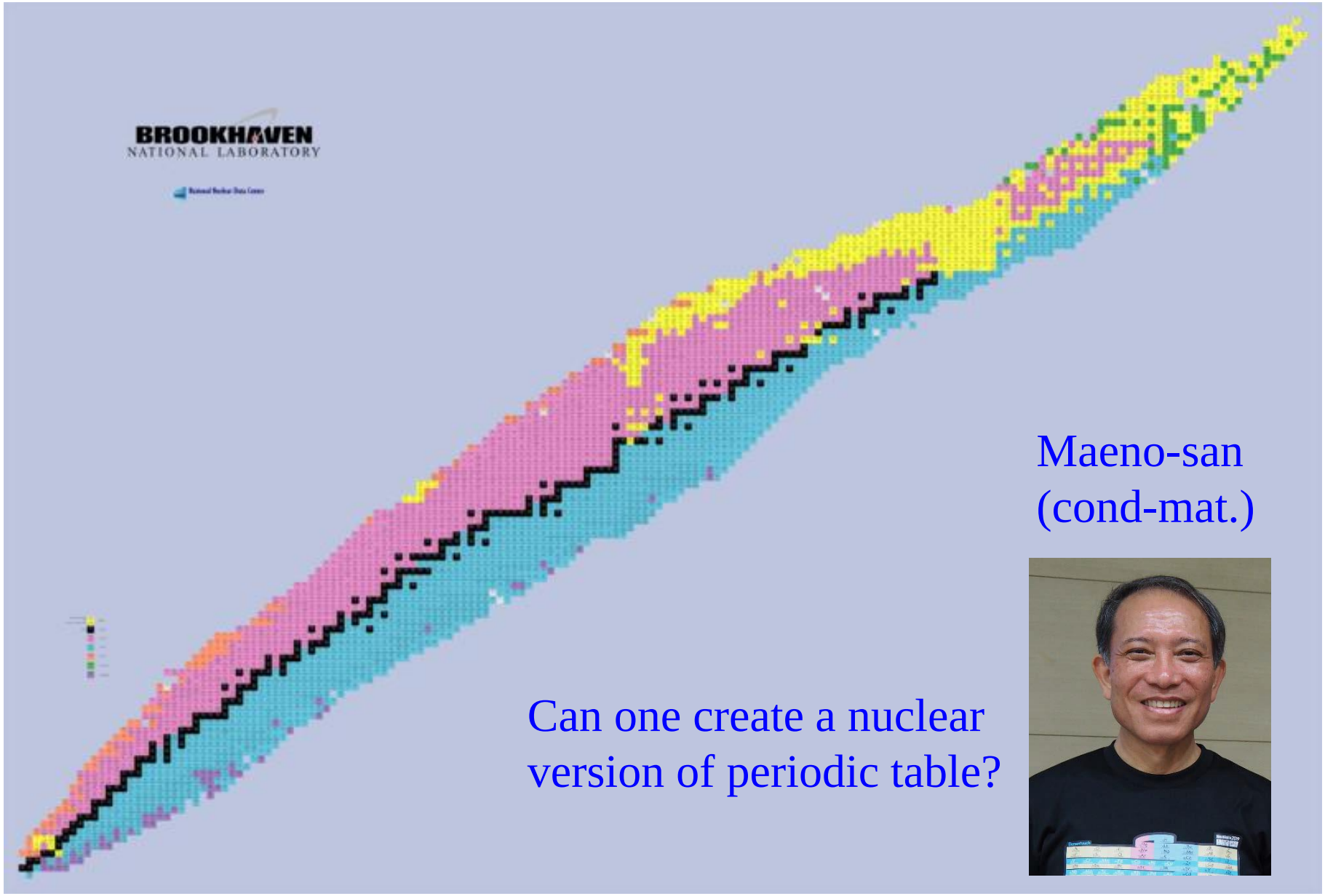
r-process nucleosynthesis (waiting point nuclei)



island of stability (superheavy nuclei)



nuclear chart



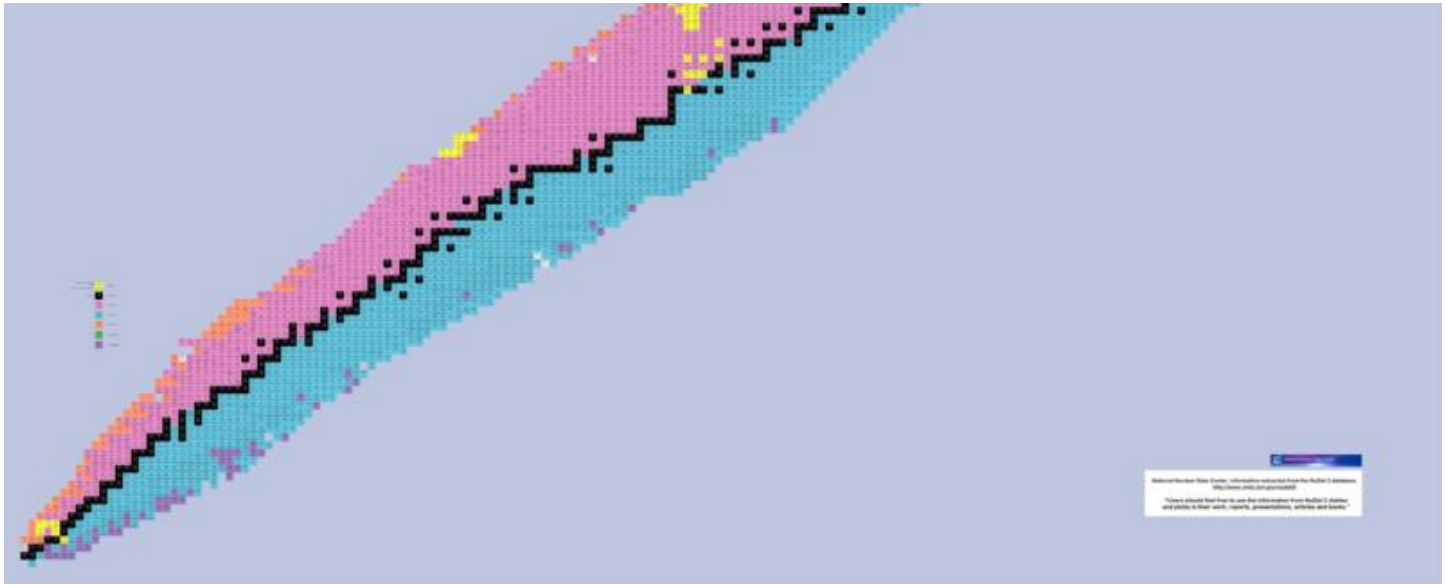
Maeno-san
(cond-mat.)

Can one create a nuclear version of periodic table?

Nuclear Periodic Table

Mapping a 2D nuclear chart onto a 1D table

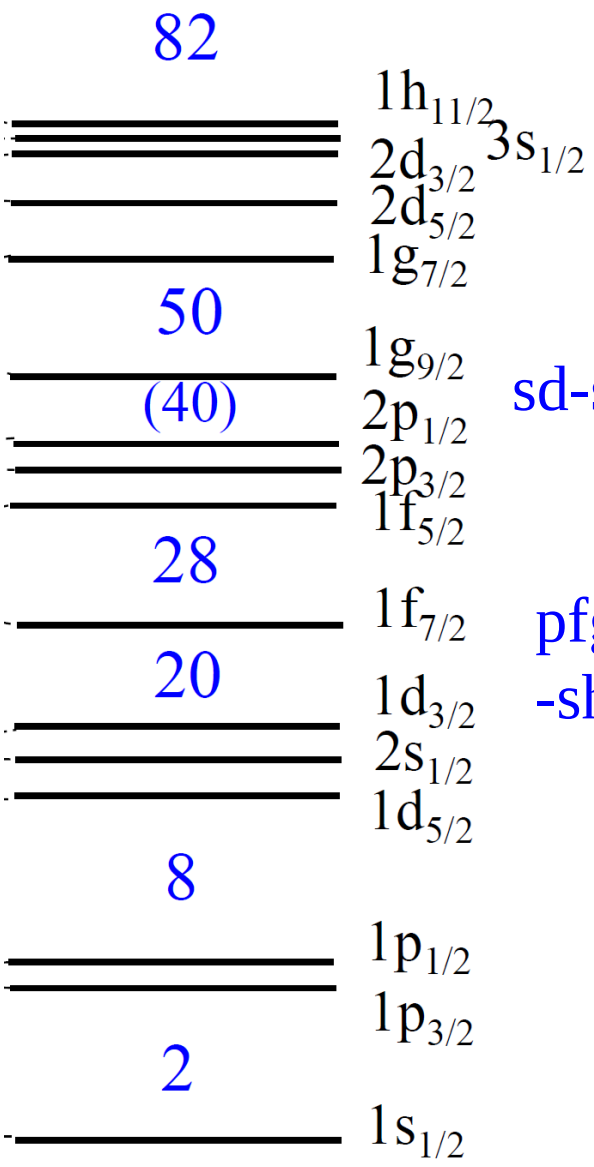
- ✓ consider protons to make a correspondence to PT of elements
- ✓ How to deal with neutrons?

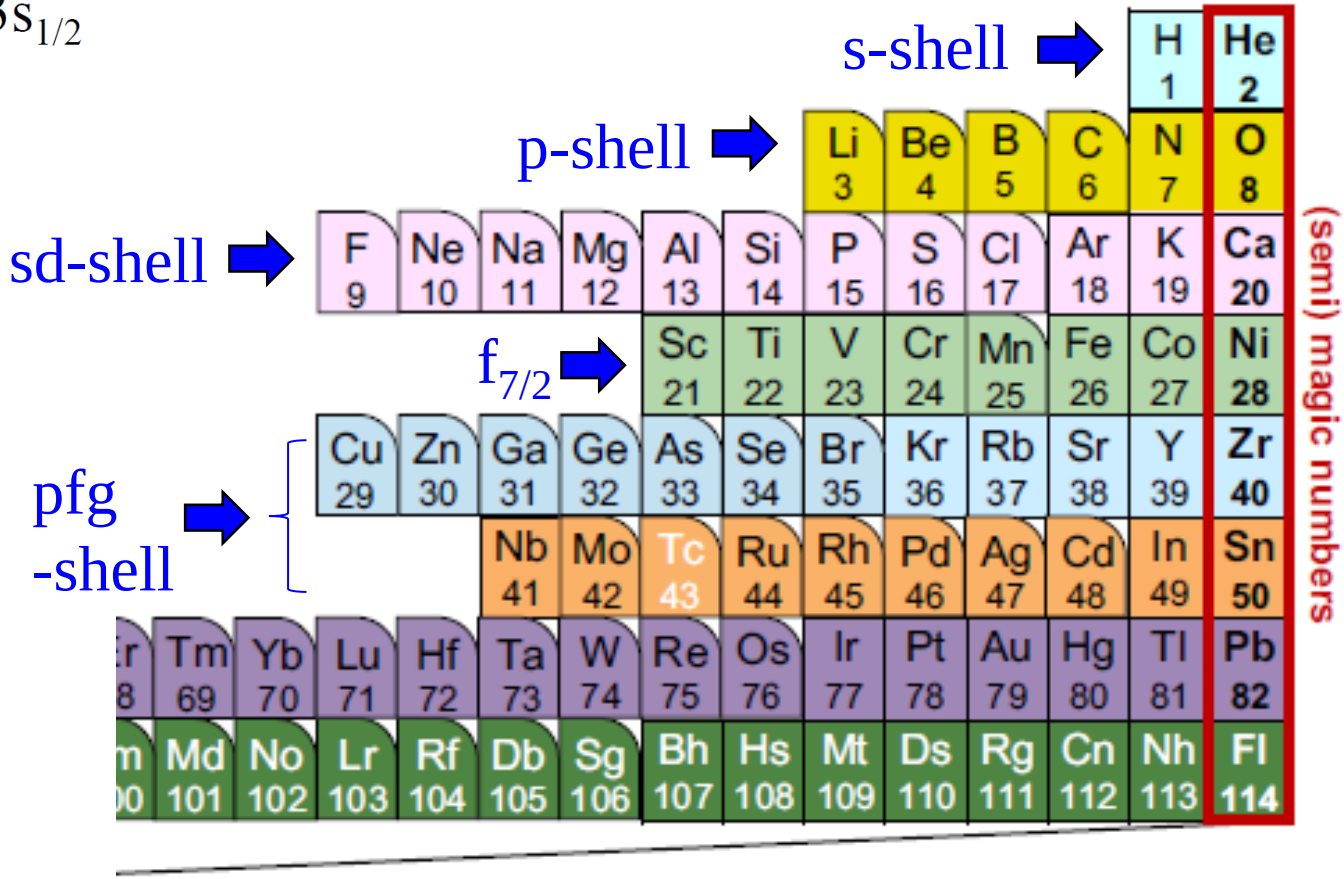


→ Select the most ‘typical’ nucleus for each element

- the largest abundance
- the longest lifetime (if no stable nucleus)

Nuclear Periodic Table





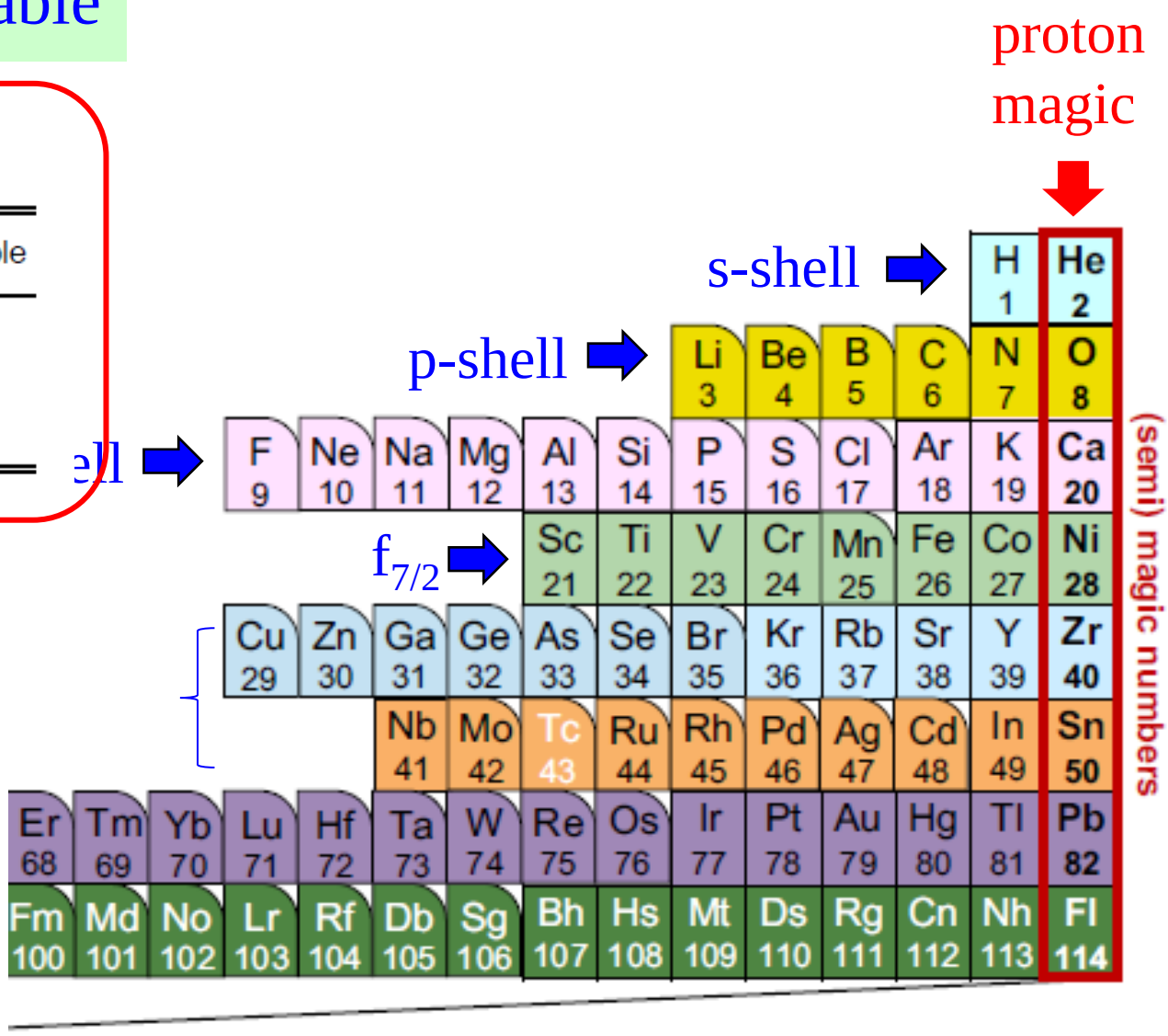
Nuclear Periodic Table

Shape and stability

	Stable	Unstable
Spherical	Nb 41	Nh 113
Deformed	Mo 42	Tc 43

- ✓ deformed nuclei : round square

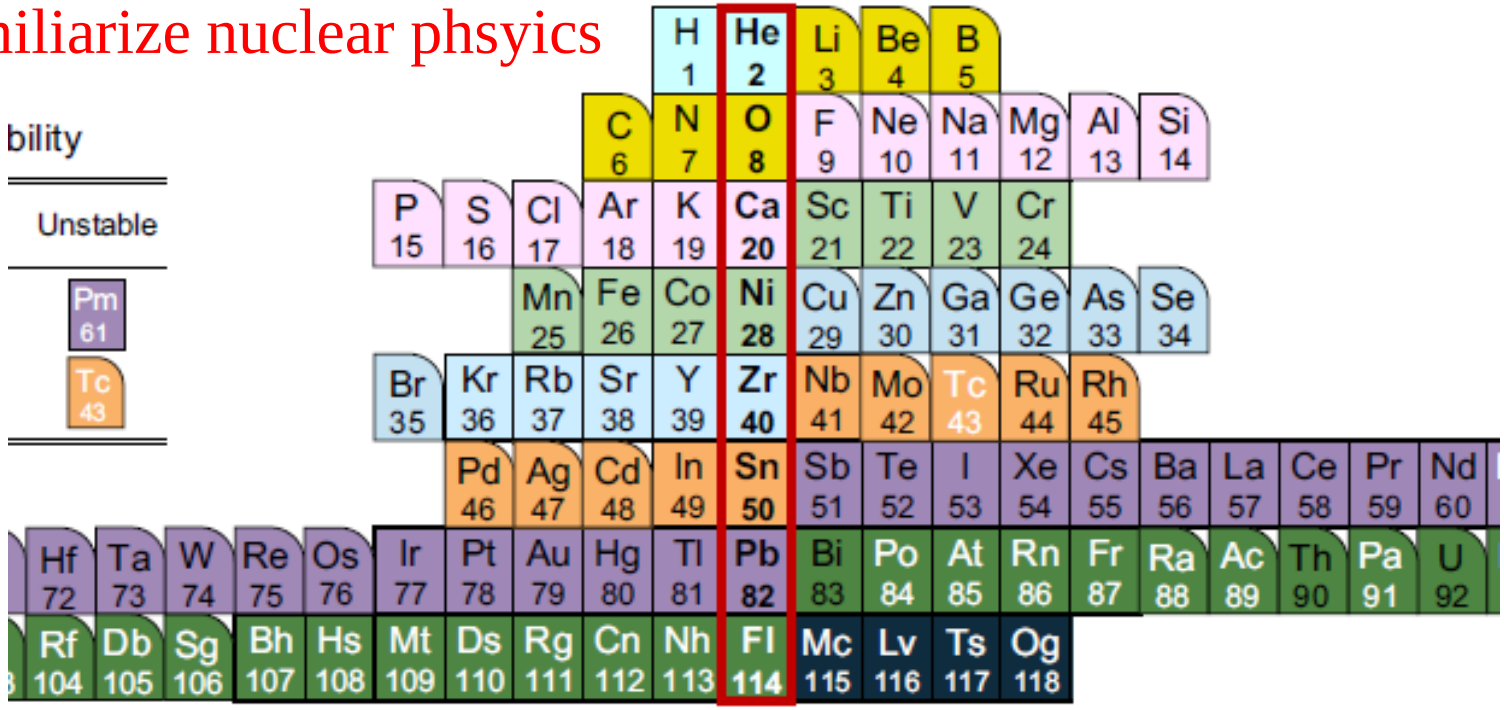
- ✓ unstable nuclei :white letters

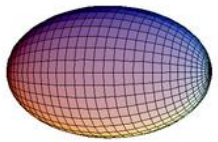


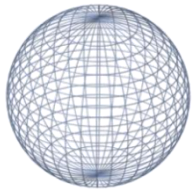
Nuclear Periodic Table

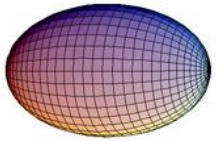
a version with proton magic nuclei at the center

a pedagogical significance
: to familiarize nuclear phsyics









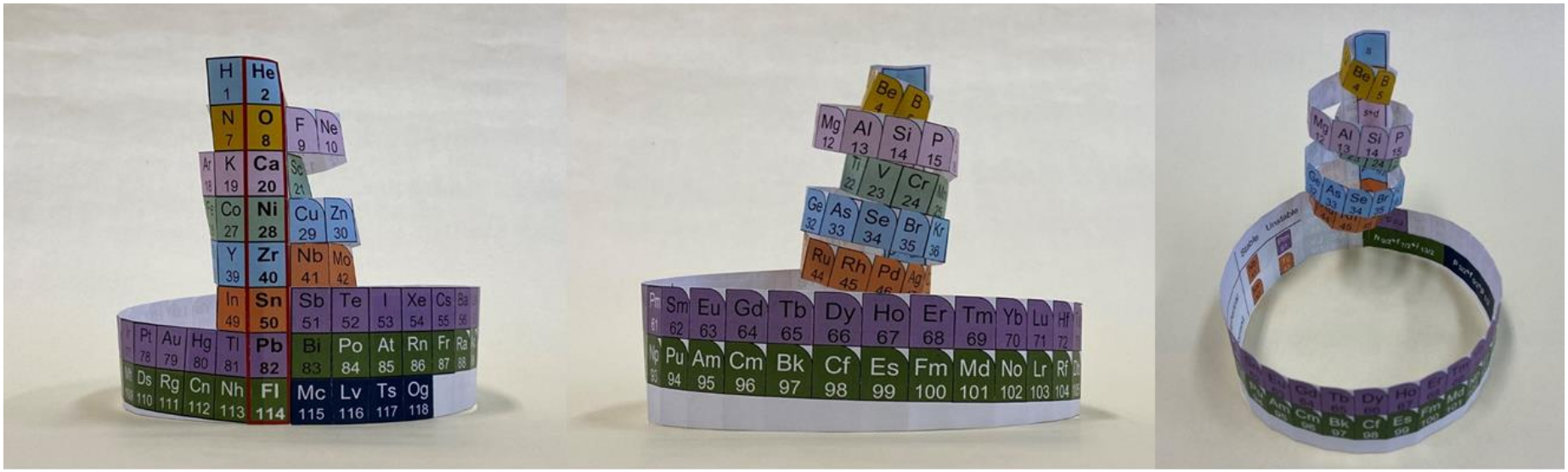
deformed

spherical

deformed

Nuclear Periodic Table

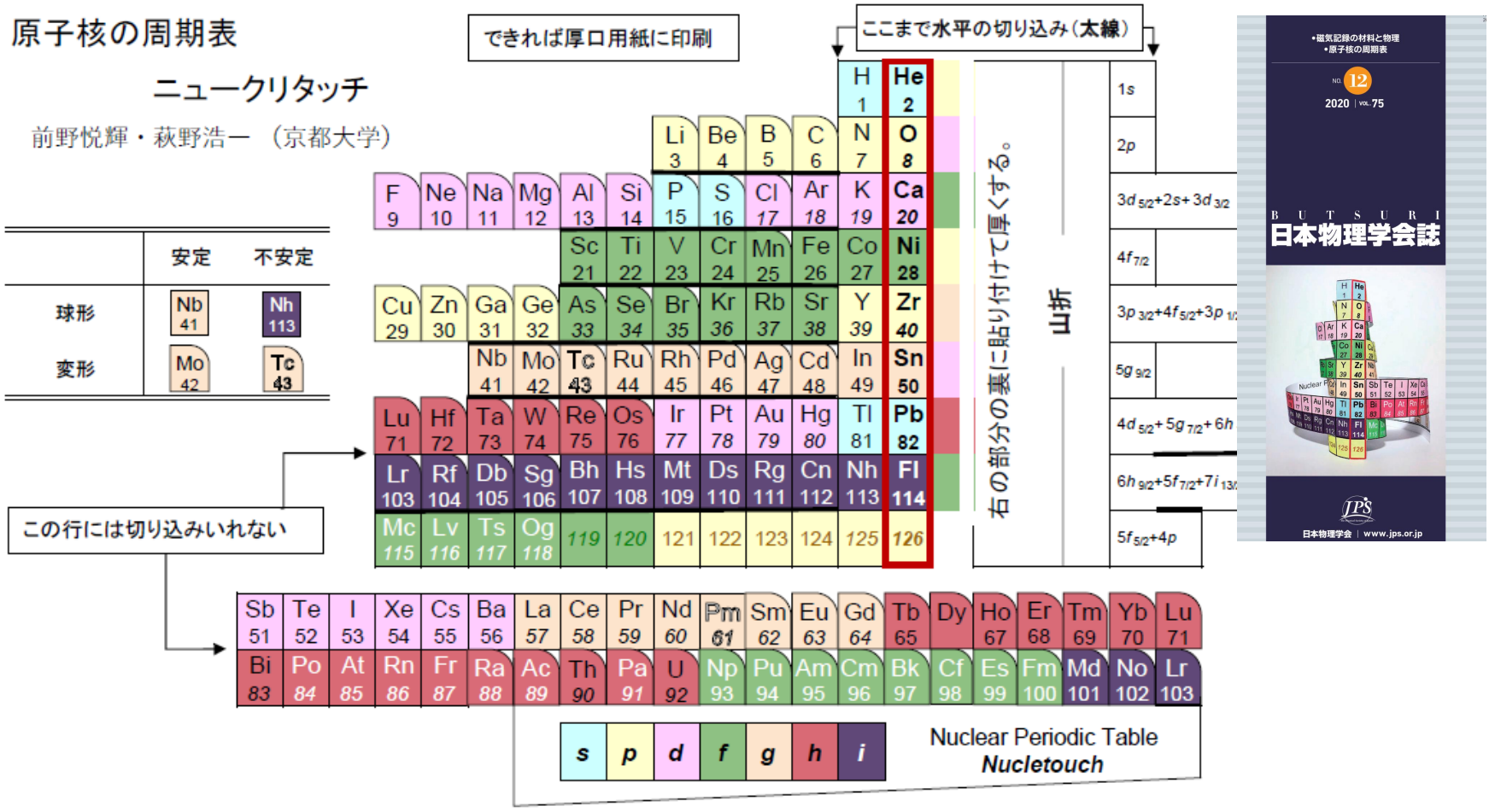
a 3D nuclear periodic table
“Nucletouch”



Nuclear Periodic Table

a 3D nuclear periodic table “Nucletouch”

日本物理学会誌 第75巻 第12号
サプルメンタルマテリアル



a paper pattern（型紙）available at a Supplemental Material page in the JPS web site

Nuclear Periodic Table

a 3D nuclear periodic table “Nucletouch”

購読はこちら [1週間無料]

讀賣新聞 オンライン

ログイン 新規登録

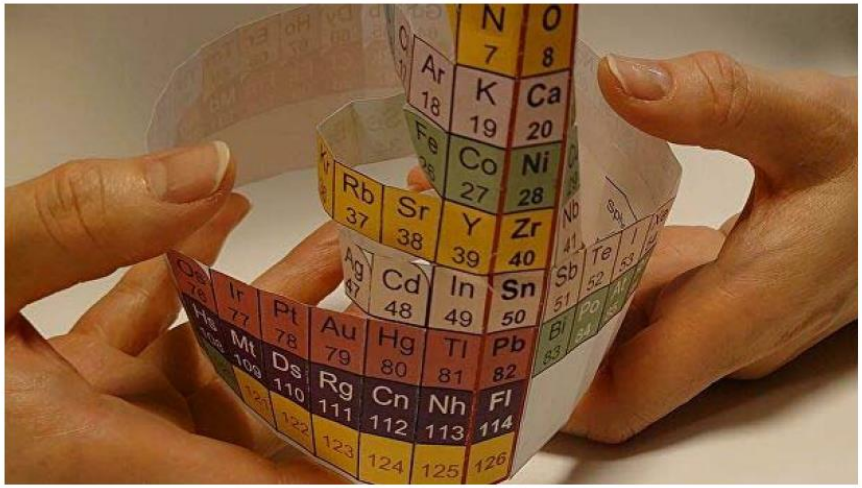
ニュース > 科学・ＩＴ

「すいへーりーべ」でおなじみの元素周期表、新パターン提案…京大が原子核の状態着目

2020/04/22 23:41

Японские физики представили новую периодическую таблицу элементов

19:34 27.05.2020 58122



© Фото : Kyoto University/Yoshiteru Maeno/Kouichi Hagino

МОСКВА, 27 мая — РИА Новости. Ученые из Киотского университета представили периодическую таблицу элементов, которая в отличие от таблицы Менделеева, где за основу взяты электроны в атоме, основана на

日本経済新聞

朝刊・夕刊 ストーリー My ニュース 日経

トップ 速報 マネー 経済・金融 政治 ビジネス マーケット テクノロジー

新しい周期表を考案 京大、原子核の性質を表現

2020/5/3付 | 日本経済新聞 朝刊

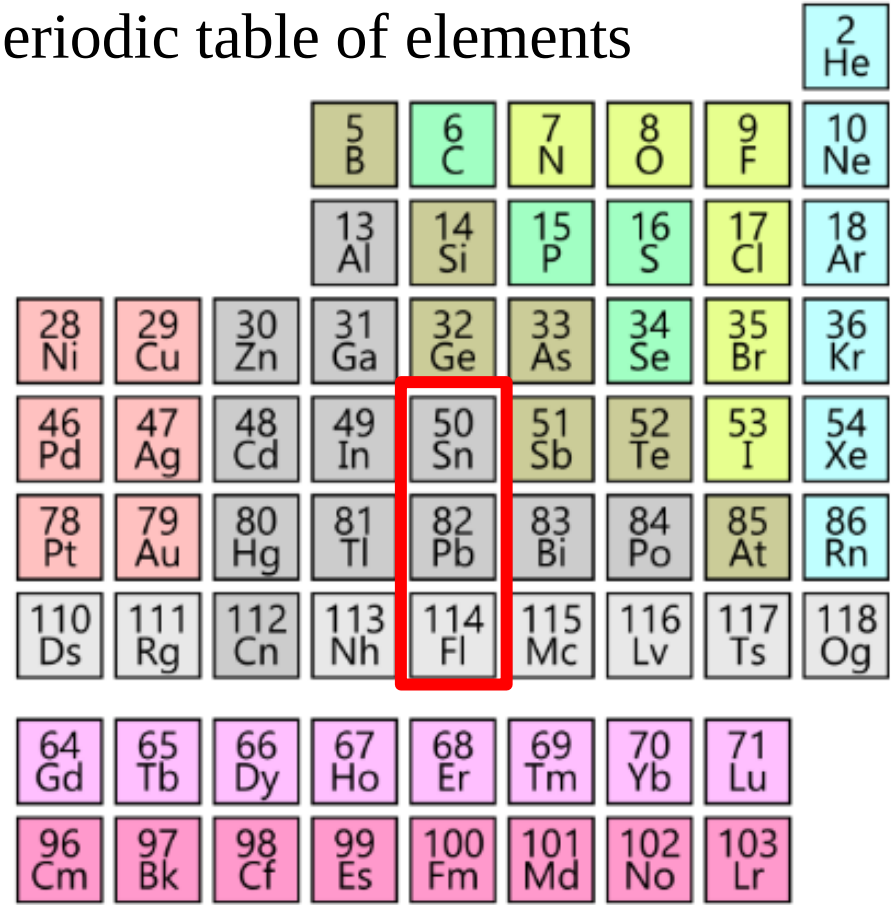
保存 共有

京都大学の前野悦輝教授と萩野浩一教授は、原子核の性質をわかりやすく表い周期表を考案した。従来の周期表が元素の化学的な性質を知るのに役立って、新しい周期表は元素の原子核の性質を知るのに使える。

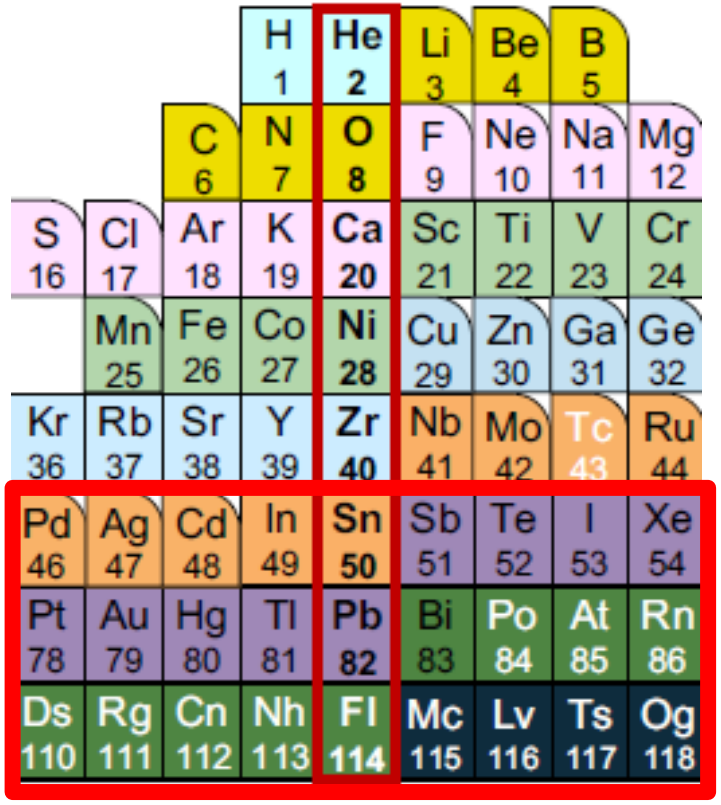
a magical coincidence

Y. Maeno, K. Hagino, and T. Ishiguro,
Found. of Chem. 23, 201 (2021)

periodic table of elements



nuclear periodic table



the nuclear magic numbers are there in the same column!
(the same elements around them)

a magical coincidence which can be recognized only after making a nuclear periodic table

Summary

Nucletouch: a 3D nuclear periodic table

- a convenient tool to familiarize nuclear physics
  - ✓ magic numbers
  - ✓ nuclear deformation
  - ✓ nuclear stability
  - ✓ similarities and differenes between atoms and nuclei

good for 1st year students at universities

話題

原子核の周期表——Magic な関係

前野悦輝 〈京都大学大学院理学研究科 maeno.yoshiteru.2e@kyoto-u.ac.jp〉
萩野浩一 〈京都大学大学院理学研究科 hagino.kouichi.5m@kyoto-u.ac.jp〉