



# RUTHENIUM

# HISTORY

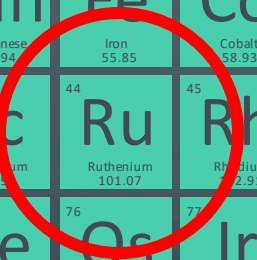
- Discovered in 1844
  - Karl Klaus in Kazan
  - First studied by Jedrzej Sniadecki 1807
    - Discarded because finds were non repeatable
- Name from the Latin word for Russia (Ruthenia)



# RUTHENIUM IN THE PERIODIC TABLE OF ELEMENTS

1 H Hydrogen 1.01																	2 He Helium 4.00
3 Li Lithium 6.94	4 Be Beryllium 9.01											5 B Boron 10.81	6 C Carbon 12.01	7 N Nitrogen 14.01	8 O Oxygen 16.00	9 F Fluorine 19.00	10 Ne Neon 20.18
11 Na Sodium 22.99	12 Mg Magnesium 24.31											13 Al Aluminum 26.98	14 Si Silicon 28.09	15 P Phosphorus 30.97	16 S Sulfur 32.06	17 Cl Chlorine 35.45	18 Ar Argon 39.95
19 K Potassium 39.10	20 Ca Calcium 40.08	21 Sc Scandium 44.96	22 Ti Titanium 47.88	23 V Vanadium 50.94	24 Cr Chromium 51.99	25 Mn Manganese 54.94	26 Fe Iron 55.85	27 Co Cobalt 58.93	28 Ni Nickel 58.69	29 Cu Copper 63.55	30 Zn Zinc 65.38	31 Ga Gallium 69.72	32 Ge Germanium 72.63	33 As Arsenic 74.92	34 Se Selenium 78.97	35 Br Bromine 79.90	36 Kr Krypton 84.80
37 Rb Rubidium 85.47	38 Sr Strontium 87.62	39 Y Yttrium 88.91	40 Zr Zirconium 91.22	41 Nb Niobium 92.91	42 Mo Molybdenum 95.95	43 Tc Technetium 98.91	44 Ru Ruthenium 101.07	45 Rh Rhodium 102.91	46 Pd Palladium 106.42	47 Ag Silver 107.87	48 Cd Cadmium 112.41	49 In Indium 114.82	50 Sn Tin 118.71	51 Sb Antimony 121.76	52 Te Tellurium 127.6	53 I Iodine 126.90	54 Xe Xenon 131.29
55 Cs Caesium 132.91	56 Ba Barium 137.33	57-71 Lanthanides	72 Hf Hafnium 178.49	73 Ta Tantalum 180.95	74 W Tungsten 183.84	75 Re Rhenium 186.21	76 Os Osmium 190.23	77 Ir Iridium 192.22	78 Pt Platinum 195.08	79 Au Gold 196.97	80 Hg Mercury 200.59	81 Tl Thallium 204.38	82 Pb Lead 207.20	83 Bi Bismuth 208.98	84 Po Polonium 208.98	85 At Astatine 209.98	86 Rn Radon 222.02
87 Fr Francium 223.02	88 Ra Radium 226.03	89-103 Actinides	104 Rf Rutherfordium [261]	105 Db Dubnium [262]	106 Sg Dubnium [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 Nh Nihonium [286]	114 Fl Flerovium [289]	115 Mc Moscovium [288]	116 Lv Livermorium [293]	117 Ts Tennessine [294]	118 Og Oganesson [294]
			57 La Lanthanum 138.91	58 Ce Cerium 140.12	59 Pr Praseodymium 140.91	60 Nd Neodymium 144.24	61 Pm Promethium 144.91	62 Sm Praseodymium 150.36	63 Eu Europium 151.96	64 Gd Gadolinium 157.25	65 Tb Terbium 158.93	66 Dy Dysprosium 162.50	67 Ho Holmium 164.93	68 Er Erbium 167.26	69 Tm Thulium 168.93	70 Yb Ytterbium 173.06	71 Lu Lutetium 174.97
			89 Ac Actinium 227.03	90 Th Thorium 232.04	91 Pa Protactinium 231.04	92 U Uranium 238.03	93 Np Neptunium 237.05	94 Pu Plutonium 244.06	95 Am Americium 243.06	96 Cm Curium 247.07	97 Bk Berkelium 247.07	98 Cf Californium 251.08	99 Es Einsteinium [252]	100 Fm Fermium 257.10	101 Md Mendelevium 258.10	102 No Nobelium 259.10	103 Lr Lawrencium [262]

- Alkali Metal
- Alkaline Earth
- Transition Metal
- Halogen
- Semi-Metal
- Non-Metal
- Basic Metal
- Lanthanide
- Actinide
- Noble Gas



# PROPERTIES

- Atomic number 44
- Electron configuration
  - [Kr] 4d<sup>7</sup>5s<sup>1</sup>
- Possible oxidation states
  - -IV, -II, 0, I, II, III, IV, V, VI, VII, VIII
- Appearance
  - Solid at room temperature
  - Metallic
  - Shiny silvery
- Atomic radius
  - 207 pm
- Electronegativity
  - 2,2
- Ionization energy
  - 7,361 eV
- Melting point
  - 2607 K
- Boiling point
  - 4423 K

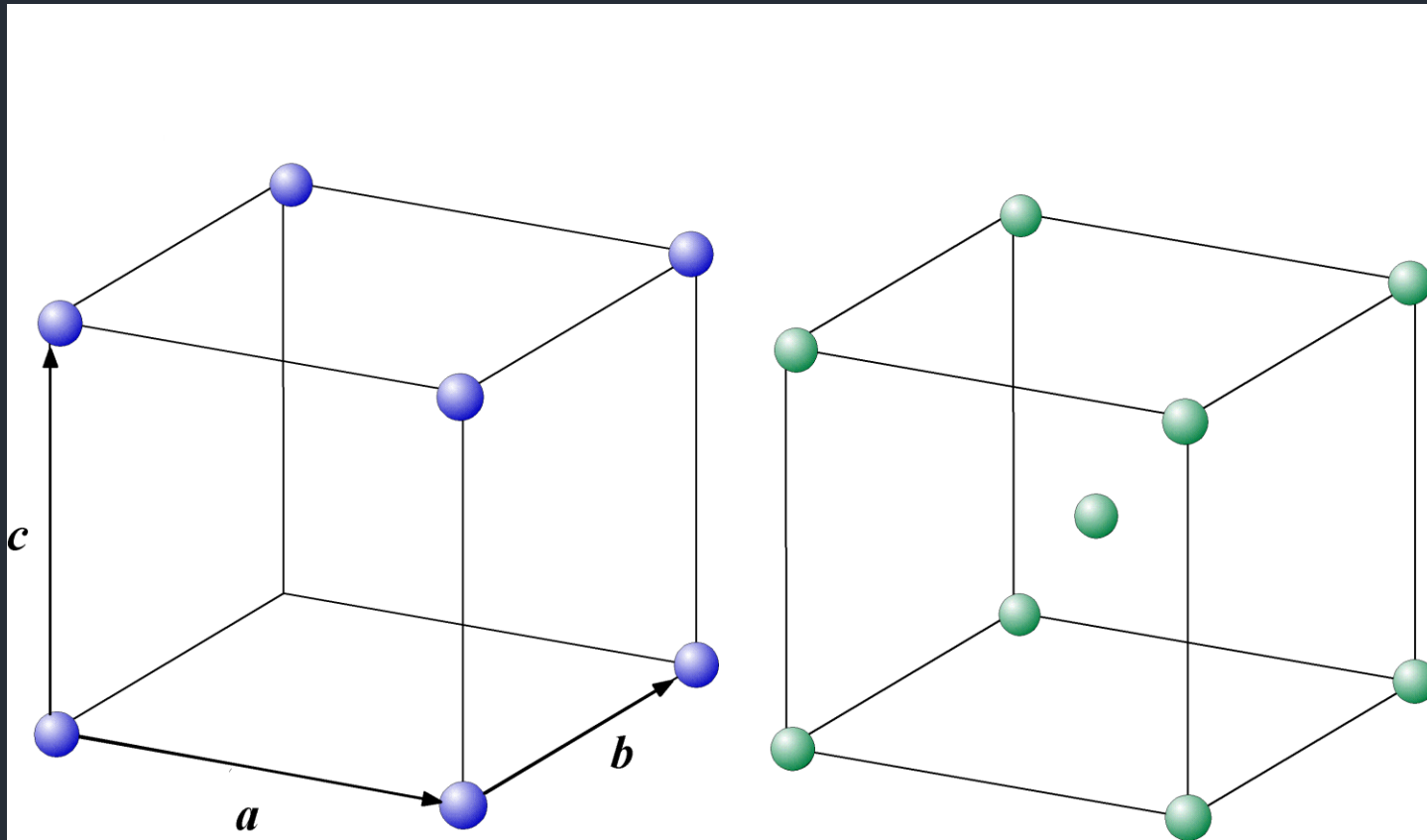


# ABUNDANCE

- Isotopes
  - Many different isotopes, most radioactive and extremely rare
  - 99, 101, 102 and 104 the most common isotopes
- 74th most abundant element in Earth's crust
  - Often found in compounds with other platinum group metals
- Largest producers
  - South africa, Russia and Zimbabwe
  - USA also has quite big reserves
  - Production has raised from  $\sim 15$  tonnes to almost 40 tonnes in the past 20 years

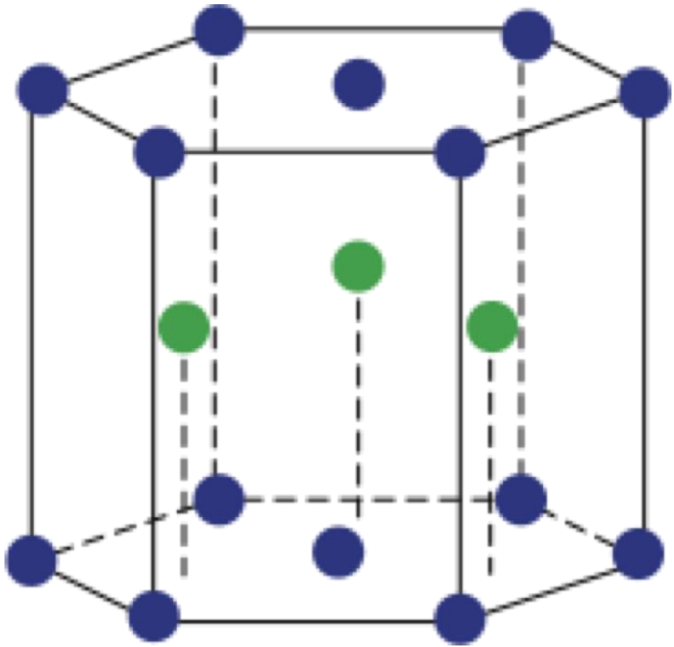
# CHEMICAL COMPOUNDS

- Ruthenium forms many organometallic compounds
  - Very useful compounds in organic synthesis and especially as catalysts
  - Grubbs catalyst ( $C_{43}H_{72}Cl_2P_2Ru$ )
    - Noble prize in 2005
- Other known compounds
  - Ruthenium (IV) oxide -  $RuO_2$
  - Both  $RuF_5$  and  $RuF_6$
  - Honeycomb structures in e.g.  $Li_2RuO_3$



DIFFERENT  
KIND OF  
CRYSTAL  
LATTICES

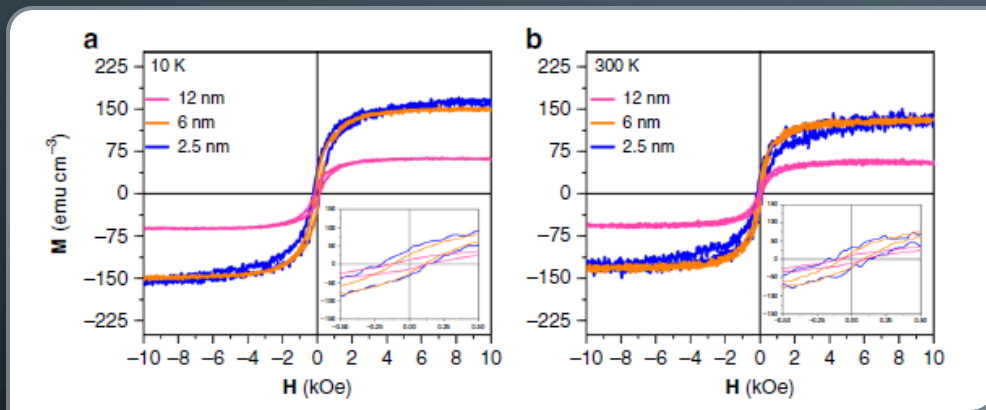
# RUTENIUM BASED THIN FILM AS FERROMAGNETIC MATERIAL



- Only Fe, Co and Ni are ferromagnetic material in the room temperature
- Naturally Ruthenium exists in the hexagonal close packed structure (HCP)
- However, by forcing it into body-centered tetragonal form (BCT) it has been proposed to have magnetic properties



# GROWING THE LAYER



- A thin layer of Ruthenium is sputtered on a  $\text{Al}_2\text{O}_3$  layer
- Thicker layers seem to magnetize worse
- These thin-film materials could be used in data storage such as hard drives and spin-transfer torque RAM

## REFERENCES

- Royal society of Chemistry, periodic table, <https://www.rsc.org/periodic-table/element/44/ruthenium>. Accessed Nov 24, 2020.
- Ruthenium – Periodic Table of Videos (May 11, 2009), [https://www.youtube.com/watch?v=wI5ZYb0hDTc&ab\\_channel=PeriodicVideos](https://www.youtube.com/watch?v=wI5ZYb0hDTc&ab_channel=PeriodicVideos). Accessed Nov. 24, 2020.
- National Center for Biotechnology Information. PubChem Element Summary for AtomicNumber 44, Ruthenium. <https://pubchem.ncbi.nlm.nih.gov/element/Ruthenium>. Accessed Nov. 24, 2020.
- <https://www.sciencedirect.com/topics/chemical-engineering/ruthenium-compound>. Accessed Nov 25, 2020.
- P. Quarterman, Congli Sun, etc: "Demonstration of Ru as the 4th ferromagnetic element at room temperature"
- Markku Sopanen: "Lecture 1: Hexagonal close packed lattice", ELEC-E3140 Semiconductor Physics