SoS RARE - HAPPY FAMILIES

SoS RARE, a project supported by the Natural Environmental Research Council UK (NERC) SoS MinErals program, is a large interdisciplinary team carrying out research to better understand Rare Earth Element (REE) deposit types, and ensure REE are responsibly sourced. Research includes developing more efficient and environmentally-friendly ways to process REE deposits, and working on metrics to compare deposit characteristics.

More information about SoS RARE can be found on the project website - sosrare.org and social media - @SosRare

Each of the cards in this Happy Families set represents an element of interest for given technology applications or metals class, including topical "critical", "strategic", and "green energy" metals. These have been allocated 'family' groups based on uses and characteristics. Family groups are colour coded, but the name for each group is also given down the left hand side of the cards in order to avoid confusion.

Chemical symbol and atomic number are provided for each element, along with information about its discovery, important uses, and the minerals in which it is most commonly found.

How to Play

3 - 6 players

Shufe and deal all the cards ace down between the players. Play starts with the person to the left of the dealer, who may ask any other player of their choice whether they have cards from a specified family - but they may only ask for a card from a family if they already have a card from that same family in their hand.

Example: player 1 has 'Eu' which belongs to the 'Elements for lighting' family, so they can ask "player 2, do you have any Elements for Lighting?"

If the player being asked has a card in the specified family, they must hand it to the player asking. If they have multiple cards in the family, they are only required to hand over one. The player who asked for and received the card, then gets another go.

Example: player 2 has W & Y, both of which are Elements for Lighting, so they hand player 1 W. Player 1 gets another go.

If the player being asked does not have any of the family specified, play passes on to the next player.

Example: player 1 also has 'Pt' (Jewellery), so they ask "player 3, do you have any Elements for Jewellery?". Player 3 does not, so play passes on to player 2.

Elements for Superalloys

RHENIUM

Re **75**

$PtAs_2$ **186.21**

Discovered by: *Walter Noddack, Ida Tacke, and Otto Berg (Germany)*

Discovered in: *1925*

Host Mineral: *sperrylite*

Uses: *alloys, catalysts, cancer treatments, radioactive research, jet engine components*

Elements for Superalloys

BERYLLIUM

Be **4**

$Be_4Si_2O_7(OH)_2$ **9.01**

Discovered by: *Friedrich Wöhler*

Discovered in: *1828*

Host Mineral: *bertrandite*

Uses: *used in super-light alloys for aerospace applications*

How to Play

[cont ...]

Once a player collects all 4 cards in the same family, they place the family down on the table.

The game can either be played to a time limit, to when the first player is out of cards, or to the 'last man standing' when all of the families have been collected.

The aim of the game is to collect the most family sets, or scoring levels for the different families can be agreed in advance - for example the 'Elements for Smartphones' family might be allocated a greater number of points.

Summary of rules:

- You must have at least one card in the family that you are asking another player for
- If you have a card in a family, you must hand it over when asked (if you have multiple, you only need to hand over one)
- If a request is unsuccessful, play passes to the next player
- The winner is the player with the most family groups (or points if families have been allocated different scores)

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Element

GROUP

CHEMICAL SYMBOL

ATOMIC NUMBER

FORMULA OF EXAMPLE MINERAL

ATOMIC WEIGHT

Discovered by:

Discovered in:

Host Mineral: *example mineral, other hosts*

Uses:

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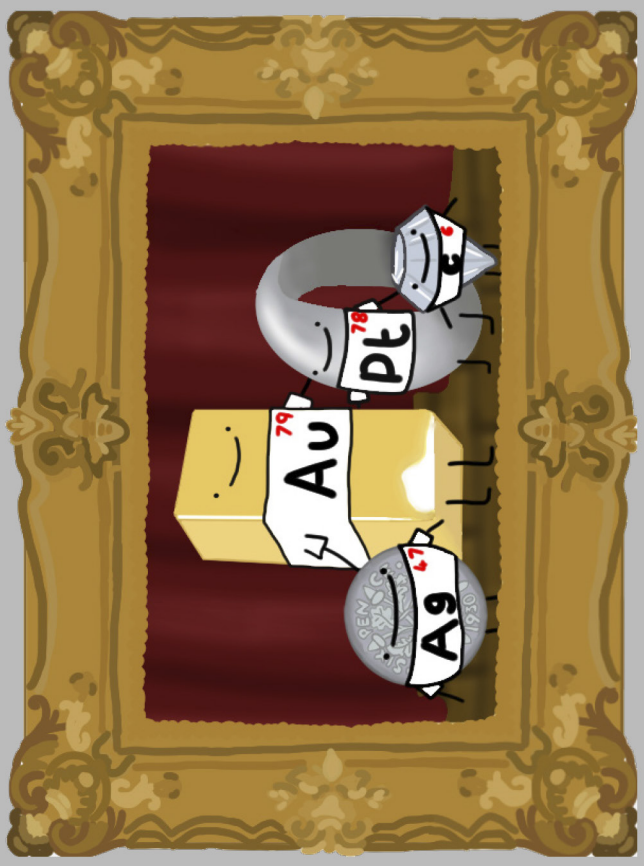

SCANDIUM

Elements for Superalloys

Sc **21**

$(Y,Ca,Ce,U,Th)(Nb,Ta,Ti)_2O_6$ **44.96**

Discovered by: *Fredrik Nilson*

Discovered in: *1879*

Host Mineral: *euxenite*

Uses: *aluminum-scandium alloys for aerospace industry, sports equipment(bicycle frames, fishing rods, baseball bats)*

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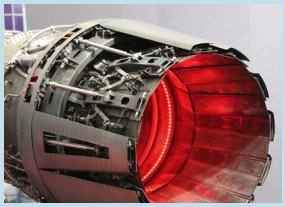
NIOBIUM

Elements for Superalloys

Nb **41**



$(Na,Ca)_2Nb_2O_6(OH,F)$ **92.91**

Discovered by: *Charles Hatchett*

Discovered in: *1801*

Host Mineral: *pyrochlore*

Uses: *superalloys for jet engines and heat resistant equipment, pipeline construction*

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SILVER

Elements for Jewellery

Ag **47**

$PtAs_2$ **107.87**

Discovered by: *prehistoric humans*

Discovered in: *evidence of silver being separated from lead ~ 4th millennium BC*

Host Mineral: *argentite, galena*

Uses: *currency, jewellery, silverware, medicine, electronics, chemical equipment, catalysis, photography, nanoparticles*

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GOLD

Elements for Jewellery

Au **79**

Au **196.97**

Discovered by: *prehistoric humans*

Discovered in: *Bronze Age*

Host Mineral: *native gold*

Uses: *jewellery, currency, electronics, medicine, food and drink*

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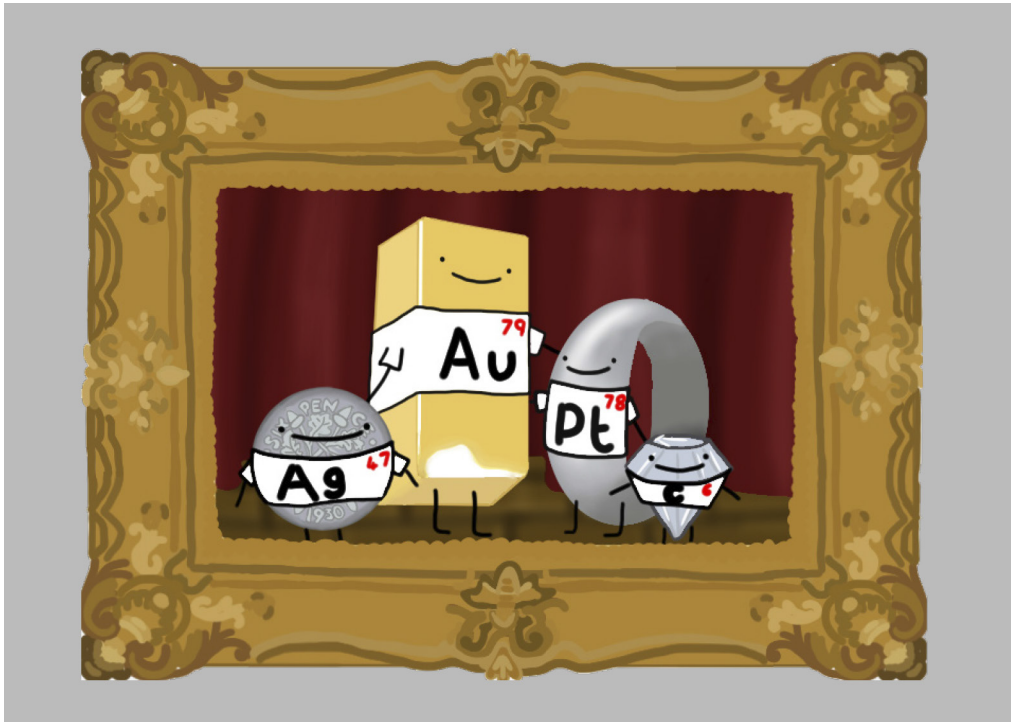
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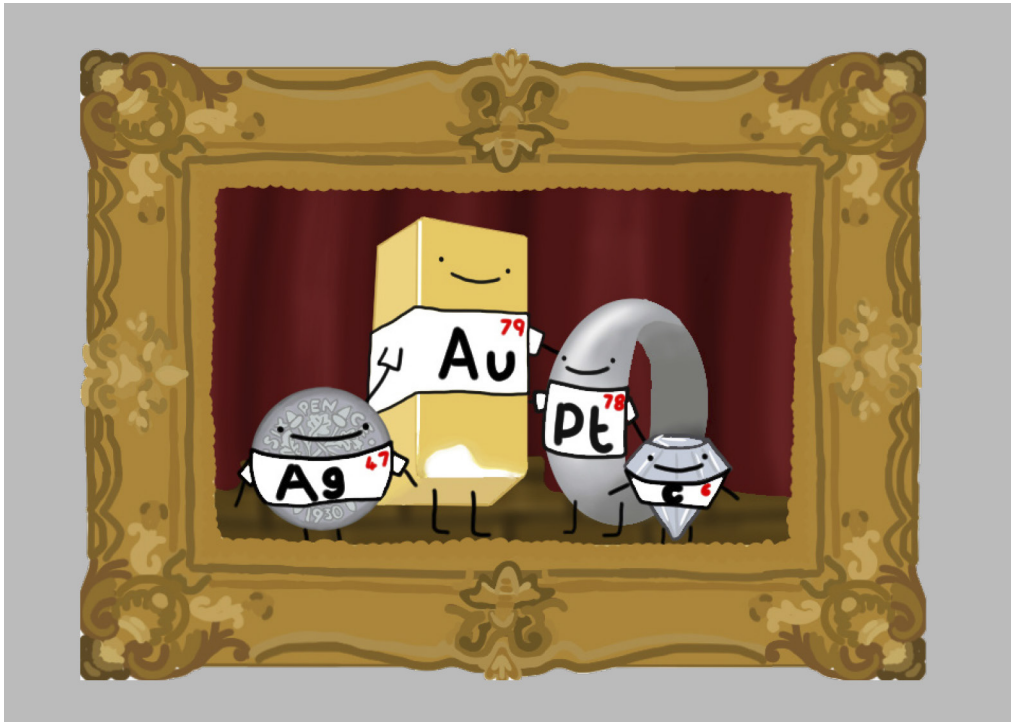
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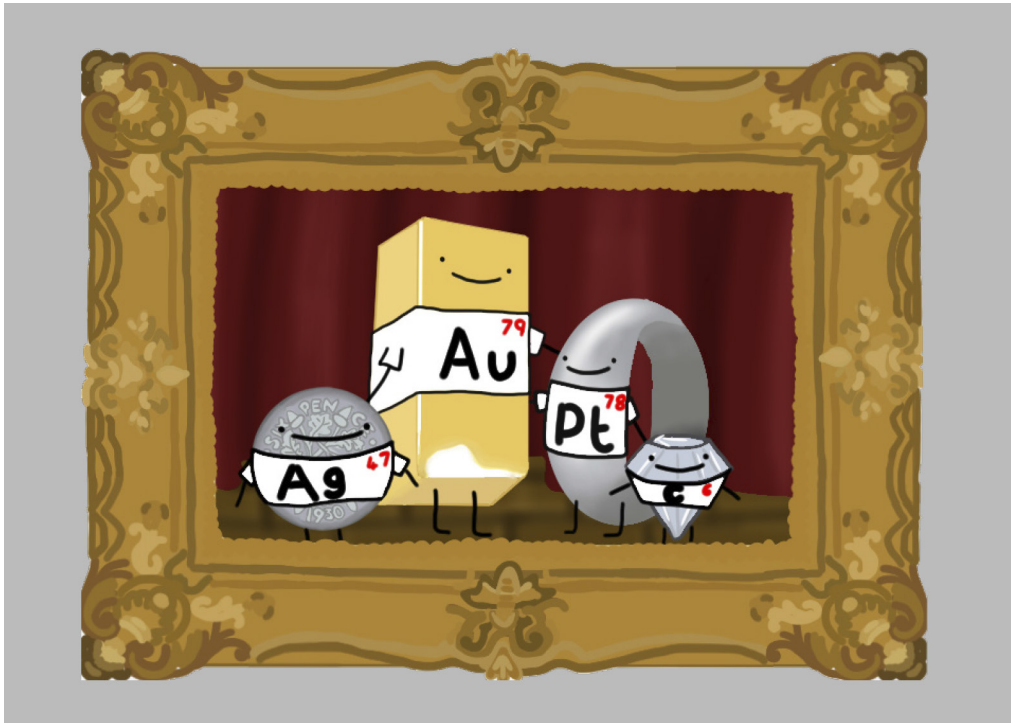
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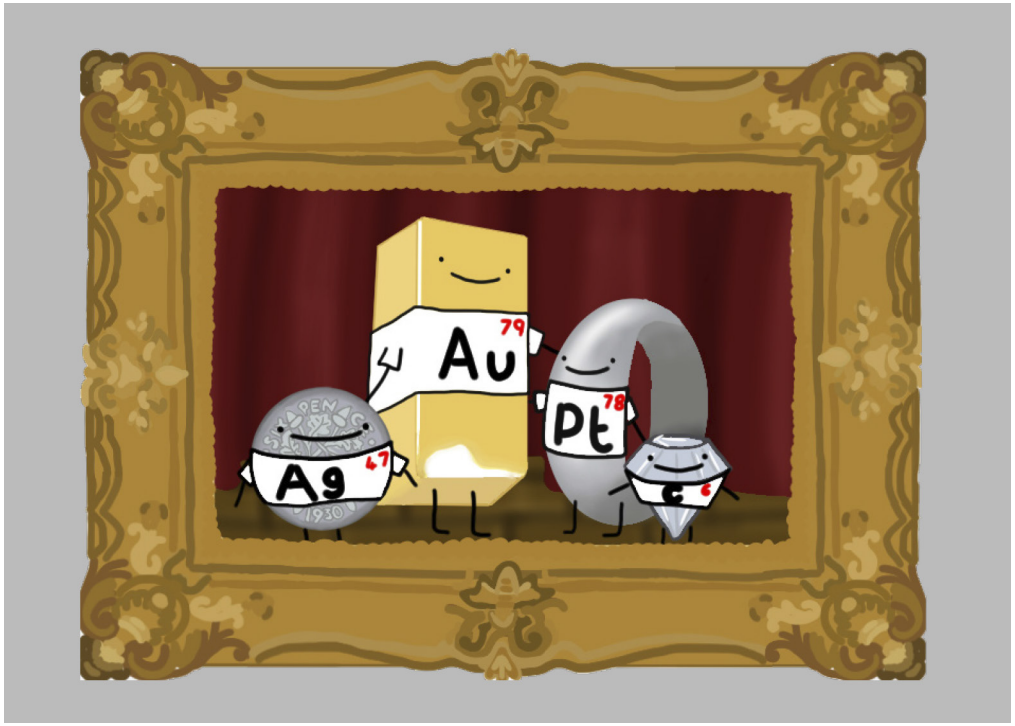
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DIAMOND

Elements for Jewellery

C **6**

C **12.01**

Discovered by: *Antoine Lavoisier (France)*

Discovered in: *1789*

Host Mineral: *diamond*

Uses: *jewellery, drill bits, cutting and polishing, heat sink (electronics)*

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PLATINUM

Elements for Jewellery

Pt **78**

$PtAs_2$ **195.08**

Discovered by: *Julius Caesar Scaliger (Italian)*

Discovered in: *1557*

Host Mineral: *sperrylite, native platinum*

Uses: *currency, jewellery, electronics, lab equipment, catalysis*

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ZINC

Elements for Manufacturing

Zn **30**

(Zn,Fe)S **65.38**

Discovered by: *Andreas Sigismund Marggraf (German)*

Discovered in: *1746*

Host Mineral: *sphalerite, smithsonite*

Uses: *anti corrosion, batteries, alloys, health supplement, tooth paste, anti dandruff*

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FLUORINE

Elements for Manufacturing

F **9**

CaF_2 **18.99**

Discovered by: *Georgius Agricola*

Discovered in: *1529*

Host Mineral: *fluorite*

Uses: *flux in steel making, sodium fluoride is used in toothpaste and in drinking water to prevent dental cavities*

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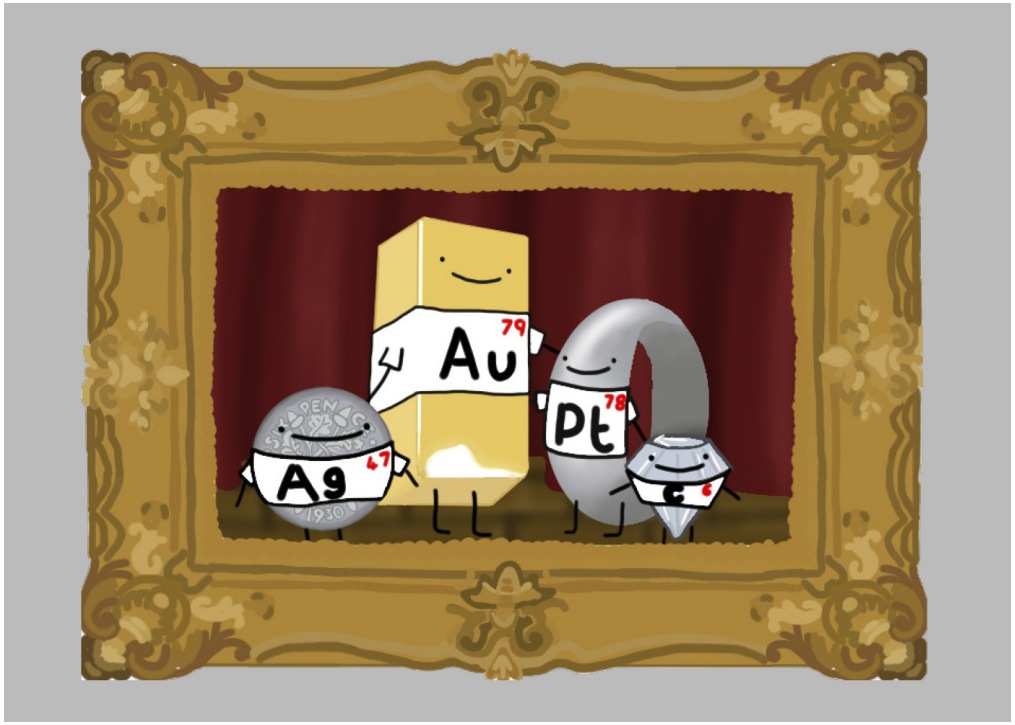
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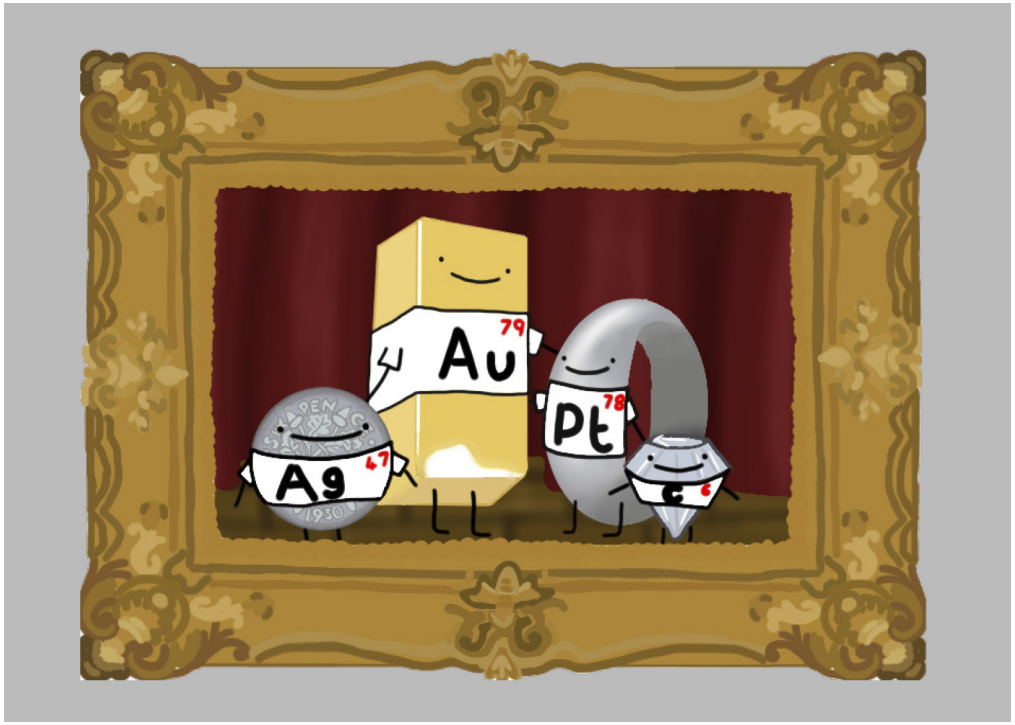
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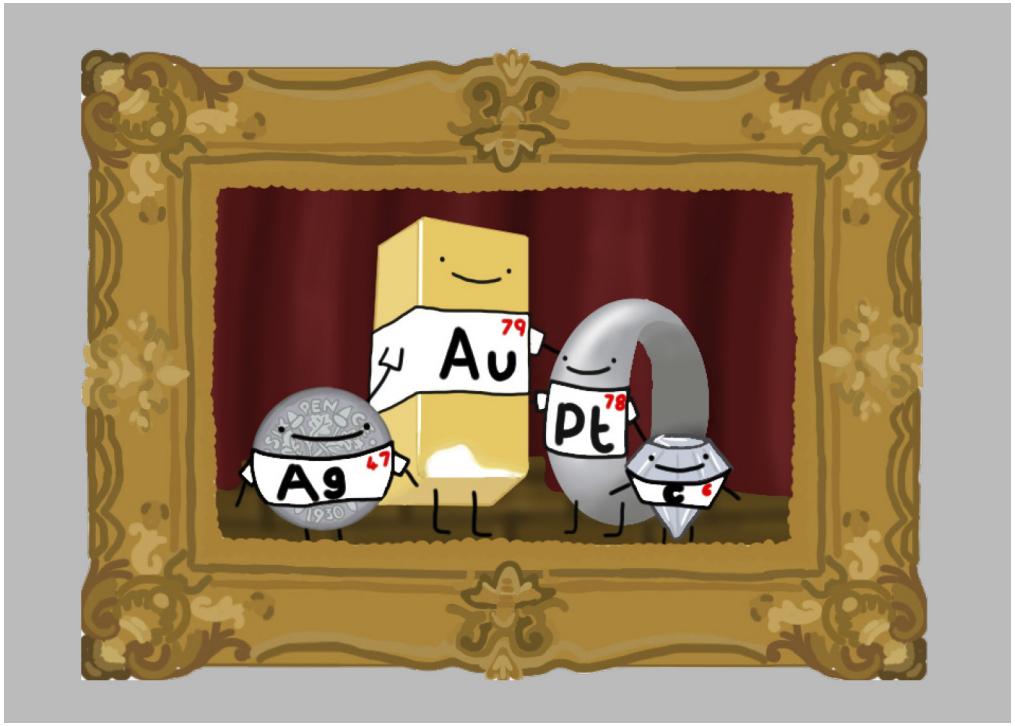
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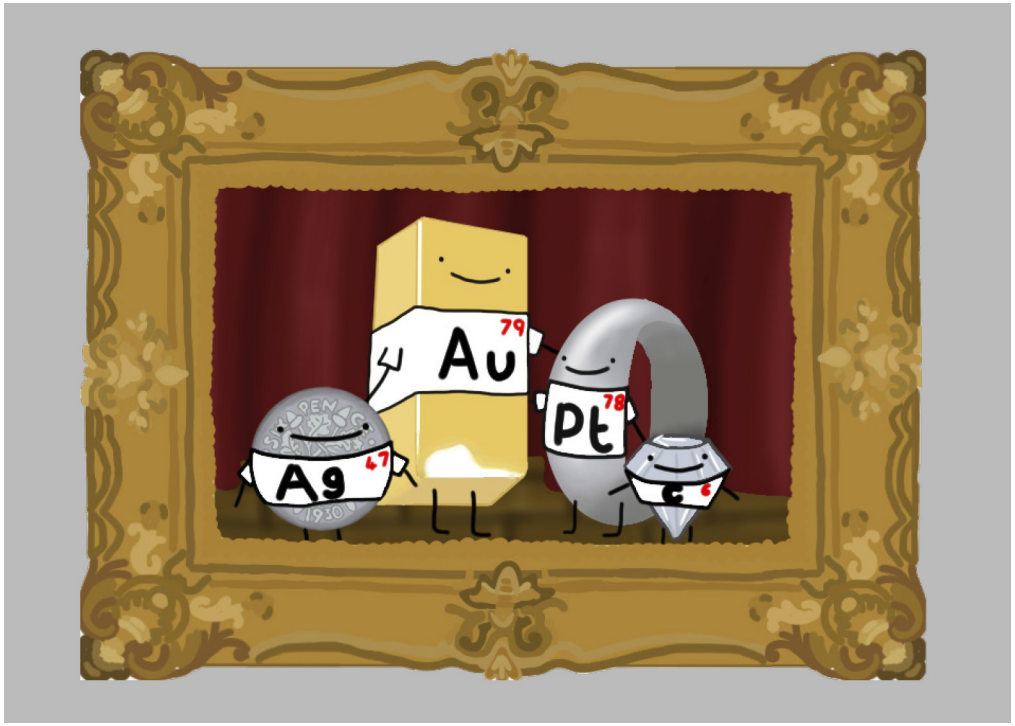
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LEAD

Elements for Manufacturing

Pb **82**

PbS **207.20**

Discovered by: *unknown*

Discovered in: *in use since ~7000 BC*

Host Mineral: *galena, cerussite*

Uses: *bullets, batteries, sheathing material, roofing material, cladding, flashing, gutters and gutter joints, roof parapets*

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IRON

Elements for Manufacturing

Fe **26**

Fe_2O_3 **55.85**

Discovered by: *unknown*

Discovered in: *in use since ~3500 BC*

Host Mineral: *hematite, magnetite*

Uses: *welding, purifying ores, steel, health supplement*

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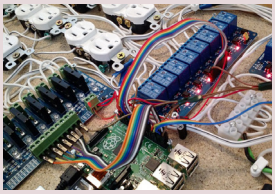
COPPER

Elements for Smartphones

Cu **29**



$CuFeS_2$ **63.55**

Discovered by: *unknown*

Discovered in: *in use since ~9000BC*

Host Mineral: *chalcopyrite, malachite, native copper*

Uses: *electronics, wiring, decorative plates, paint pigments, coinage, bacteriostatic agents, fungicides, wood preservatives*

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TANTALUM

Elements for Smartphones

Ta **73**

$(Fe,Mn)Ta_2O_6$ **180.95**

Discovered by: *Anders Ekeberg (Sweden)*

Discovered in: *1802*

Host Mineral: *tantalite*

Uses: *electronic equipment, as a substitute for platinum*

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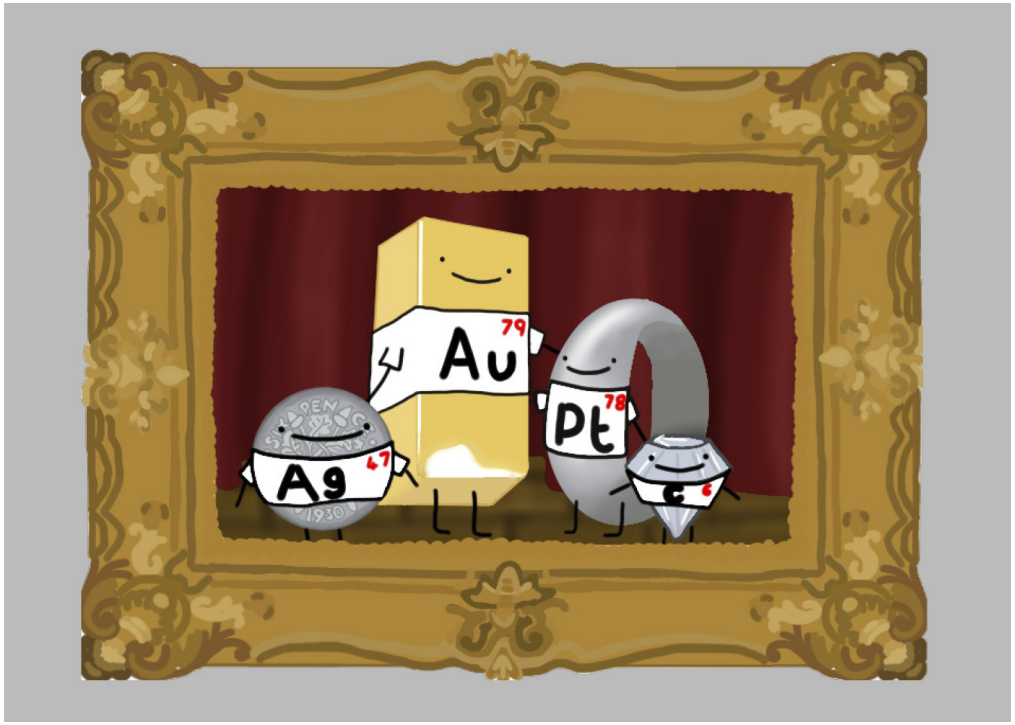
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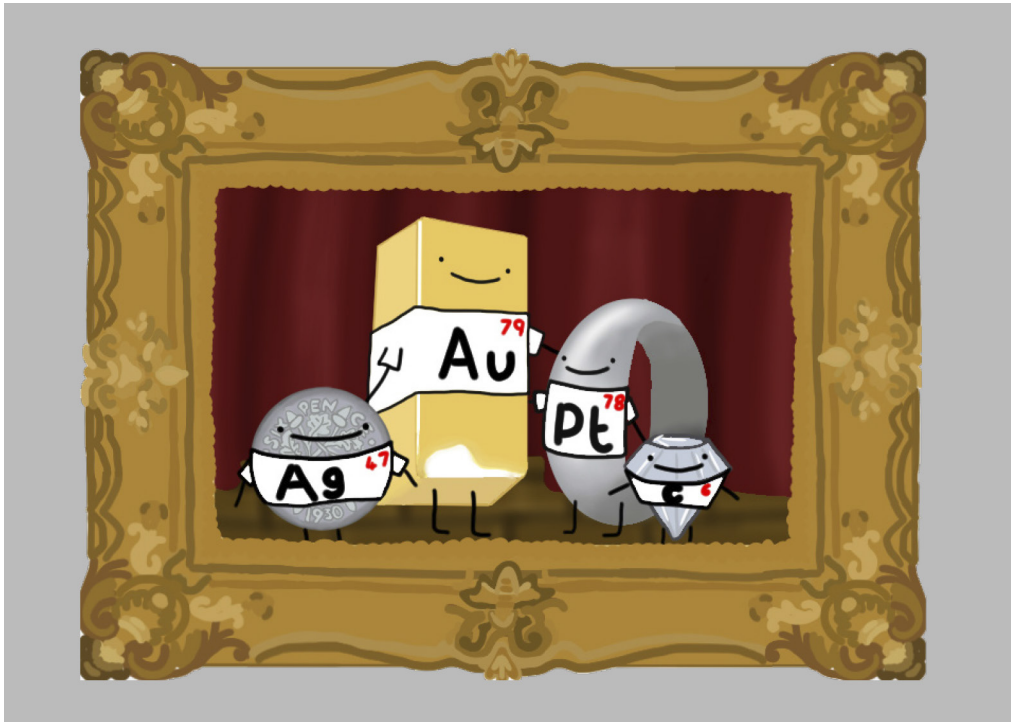
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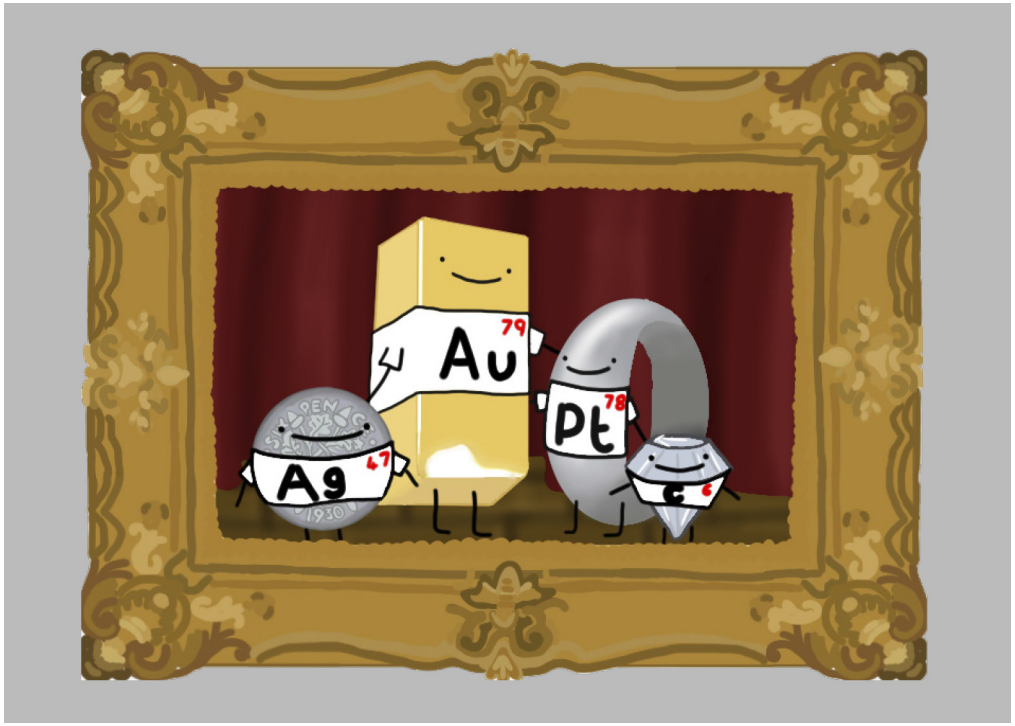
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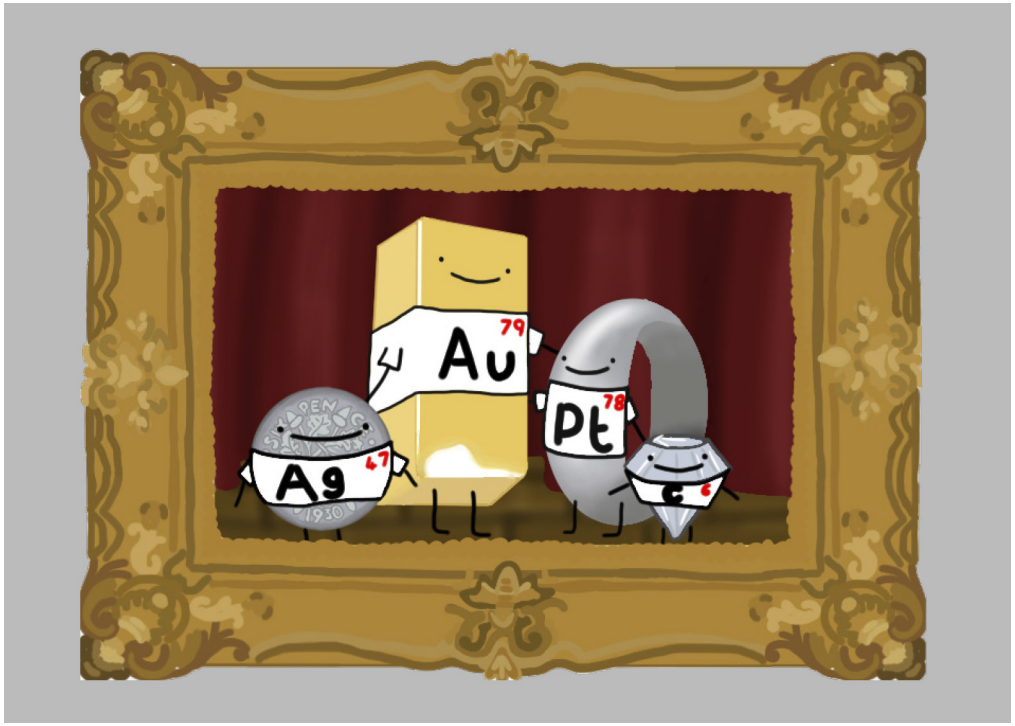
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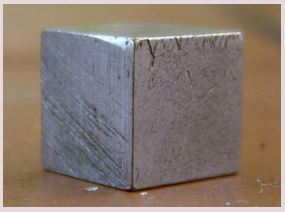
Elements for Smartphones

TIN

Sn **50**



SnO_2 **118.71**

Discovered by: *unknown*

Discovered in: *Bronze Age*

Host Mineral: *cassiterite*

Uses: *Lead-free solder, electronics, tin plating (prevents corrosion), glass making, Li-ion batteries*

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Elements for Smartphones

INDIUM

In **49**

(Zn,Fe)S **114.82**

Discovered by: *Ferdinand Reich and Hieronymous Theodor Richter (Germany)*

Discovered in: *1863*

Host Mineral: *sphalerite*

Uses: *touch screen technology in mobile phones, semiconductors, high vacuum seals, batteries, as a stabliser*

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Elements for Batteries

LITHIUM

Li **3**

$LiAl(SiO_3)_2$ **6.94**

Discovered by: *Johan August Arfwedson (Sweden)*

Discovered in: *1817*

Host Mineral: *spodumene, petalite, brines*

Uses: *batteries, ceramics and glass, electronics, lubricating grease, various medical uses*

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Elements for Batteries

CARBON

C **6**

C **12.01**

Discovered by: *Carl Wilhelm Scheele (Sweden)*

Discovered in: *1779*

Host Mineral: *graphite*

Uses: *(graphite) electrode in Li batteries, pencils, charcoal, cloth, steel, carbon fibre, printing ink*

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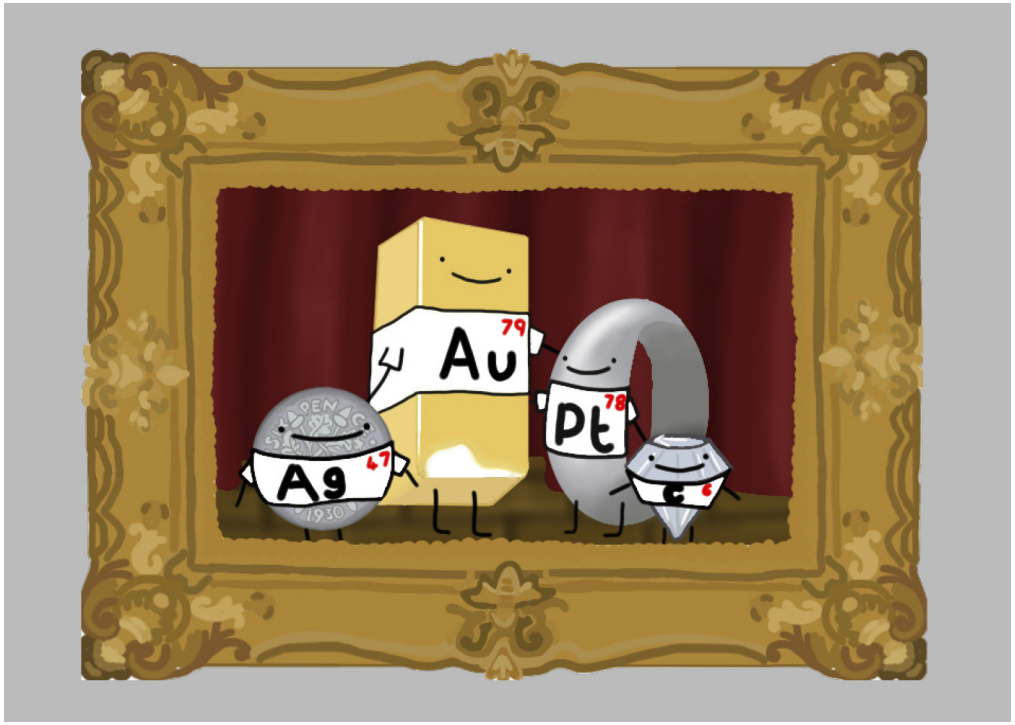
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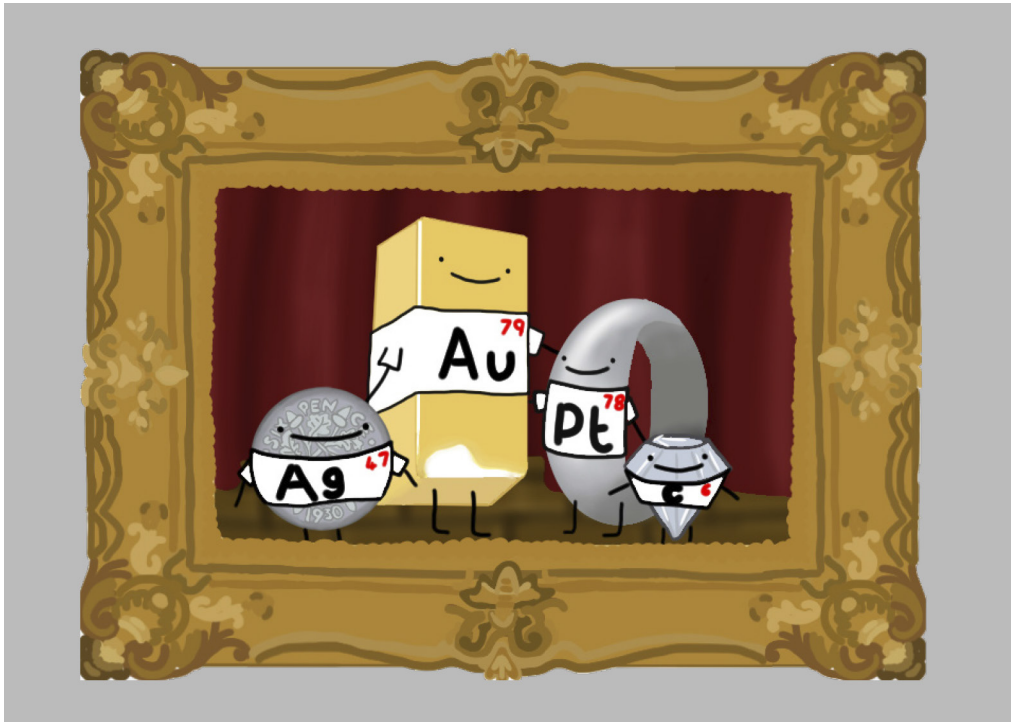
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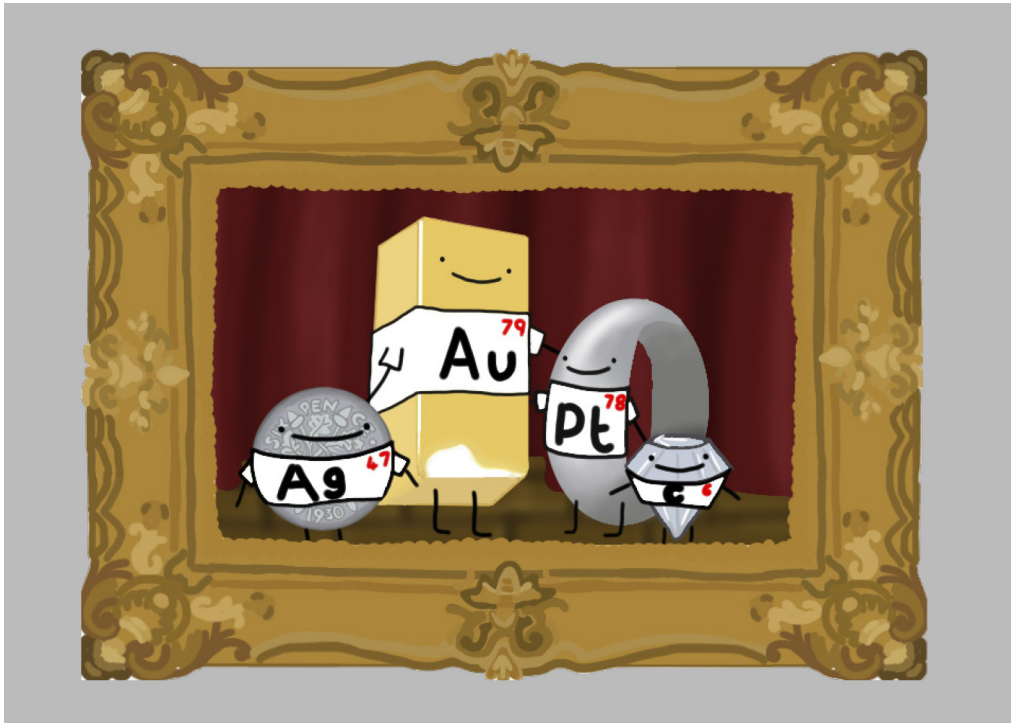
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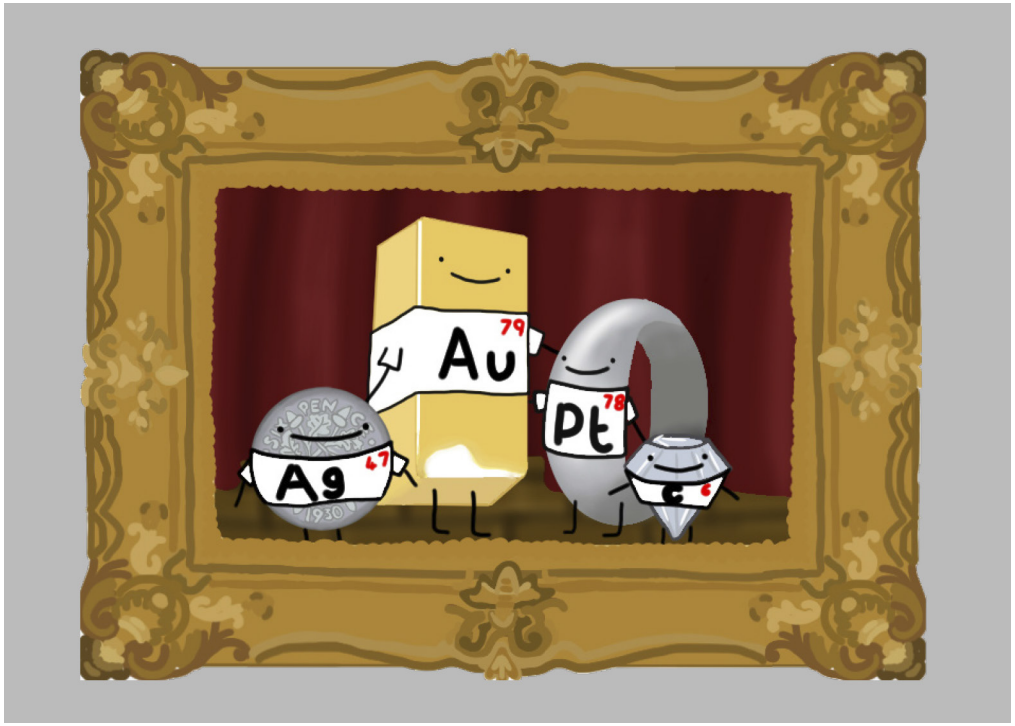
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Elements for Batteries

COBALT

Co **27**

$CoO(OH)$ **58.93**

Discovered by: *Georg Brandt (Sweden)*

Discovered in: *1735*

Host Mineral: *heterogenite, cobaltite*

Uses: *electrode in Li batteries, alloys, catalysts, pigments and colouring, radioisotopes*

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Elements for Batteries

NICKEL

Ni **28**

$(Fe,Ni)_9S_8$ **58.69**

Discovered by: *Baron Axel Fredrik Cronstedt (Sweden)*

Discovered in: *1751*

Host Mineral: *pentlandite, garnierite*

Uses: *NiMH (Nickel Metal Hydride) batteries, magnets, electric guitar strings, microphone capsules, plating on plumbing fixtures*

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Elements for Solar Power

SILICON

Si **14**

SiO_2 **28.09**

Discovered by: *Jöns Jakob Berzelius (Sweden)*

Discovered in: *1823*

Host Mineral: *quartz*

Uses: *solar power, abrasives and components of high-strength ceramics, cement, computers, mobile phones, synthetic polymers (silicones)*

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Elements for Solar Power

SELENIUM

Se **34**

$CuFeS_2$ **78.97**

Discovered by: *Jöns Jacob Berzelius (Sweden)*

Discovered in: *1917*

Host Mineral: *sulphide ores (chalcopyrite) - replacing sulphur*

Uses: *glass making, pigments, semiconductors, photocells, DC power surge protectors*

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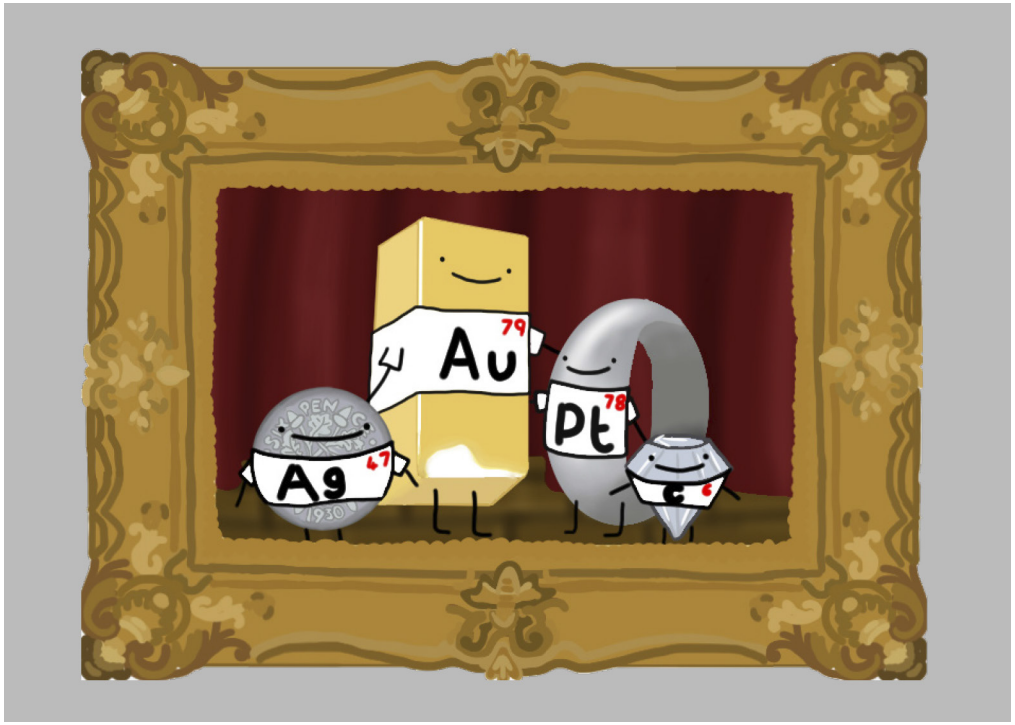
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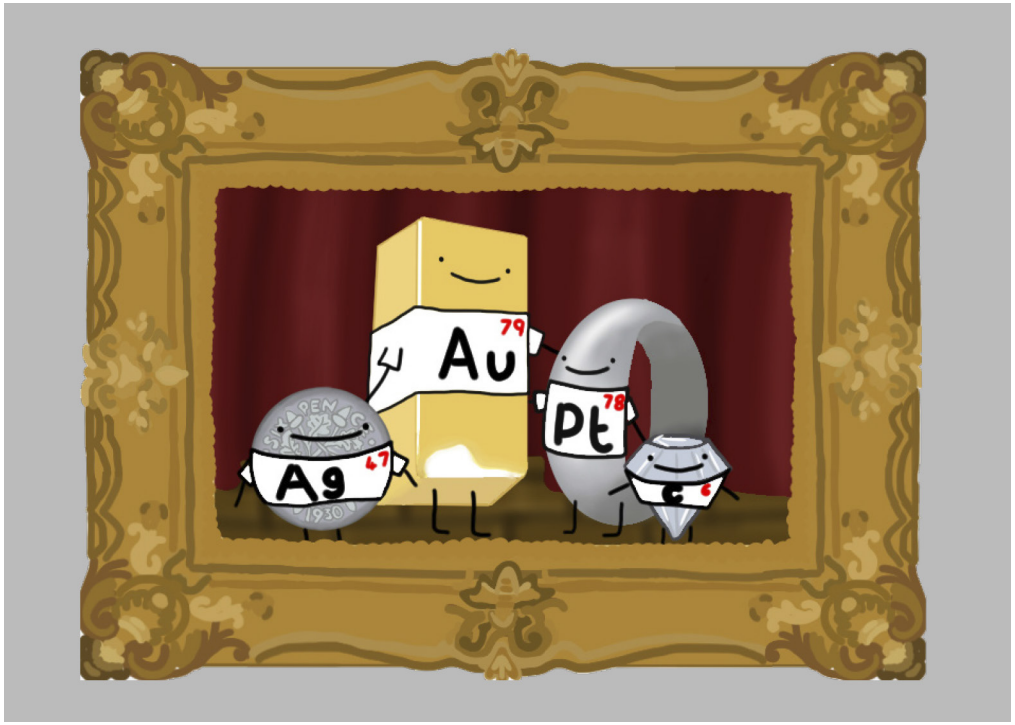
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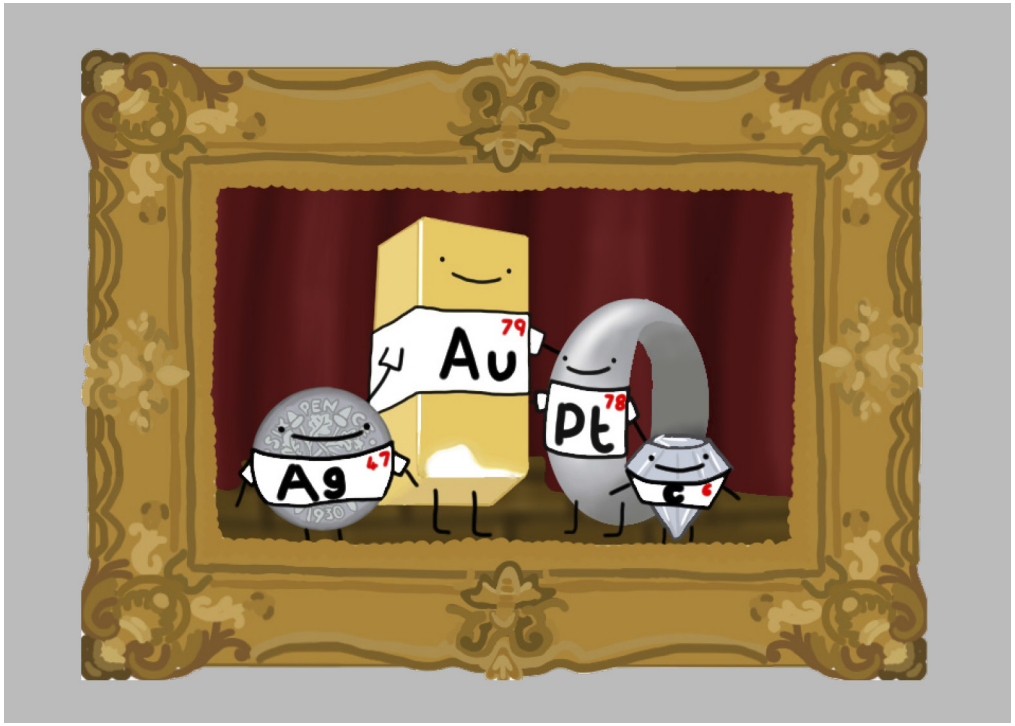
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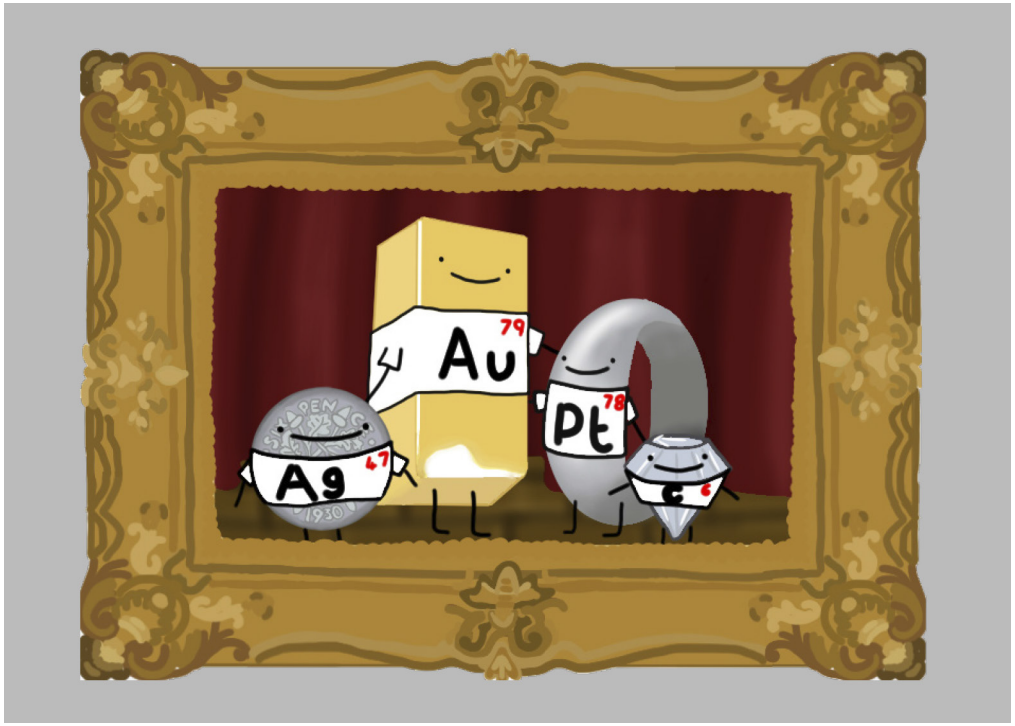
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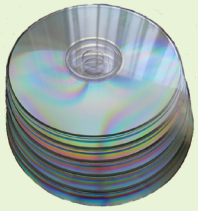
TELLURIUM

Elements for Solar Power

Te **52**



PbTe **127.60**

Discovered by: *Franz-Joseph Müller von Reichenstei / Pál Kitaibel (Austria)*

Discovered in: *1782 / 1789*

Host Mineral: *telluride minerals (altaite)*

Uses: *alloys, solar panels, phase-change memory chips, media layer of rewritable optical discs(CD-RW, DVD-RW, Blu-ray)*

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GALLIUM

Elements for Solar Power

Ga **31**

(Zn,Fe)S **69.72**

Discovered by: *Paul Emile Lecoq de Boisbaudran (France)*

Discovered in: *1875*

Host Mineral: *sphalerite*

Uses: *electronics, microwave circuits, high-speed switching circuits, infrared circuits, alloys, LEDS, jewellery*

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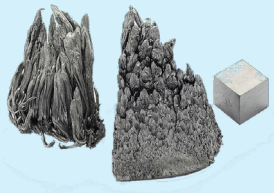
YTTRIUM

Elements for Lighting

Y **39**



YPO_4 **88.91**

Discovered by: *Friedrich Wöhler (Sweden)*

Discovered in: *1828*

Host Mineral: *xenotime, eudialyte, clays*

Uses: *LEDs, compact fluorescent lightbulbs, production of electrodes, electrolytes, electronic filters, lasers, superconductors, various medical applications, phosphors*

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EUROPIUM

Elements for Lighting

Eu **63**

$Ce(CO_3)F$ **151.96**

Discovered by: *Paul Émile Lecoq de Boisbaudran (Europe)*

Discovered in: *1890*

Host Mineral: *monazite, bastnäsite, xenotime*

Uses: *red phosphor in mobile phones, TVs and computer monitors, banknote security, fluorescent lamps, quantum memory chips*

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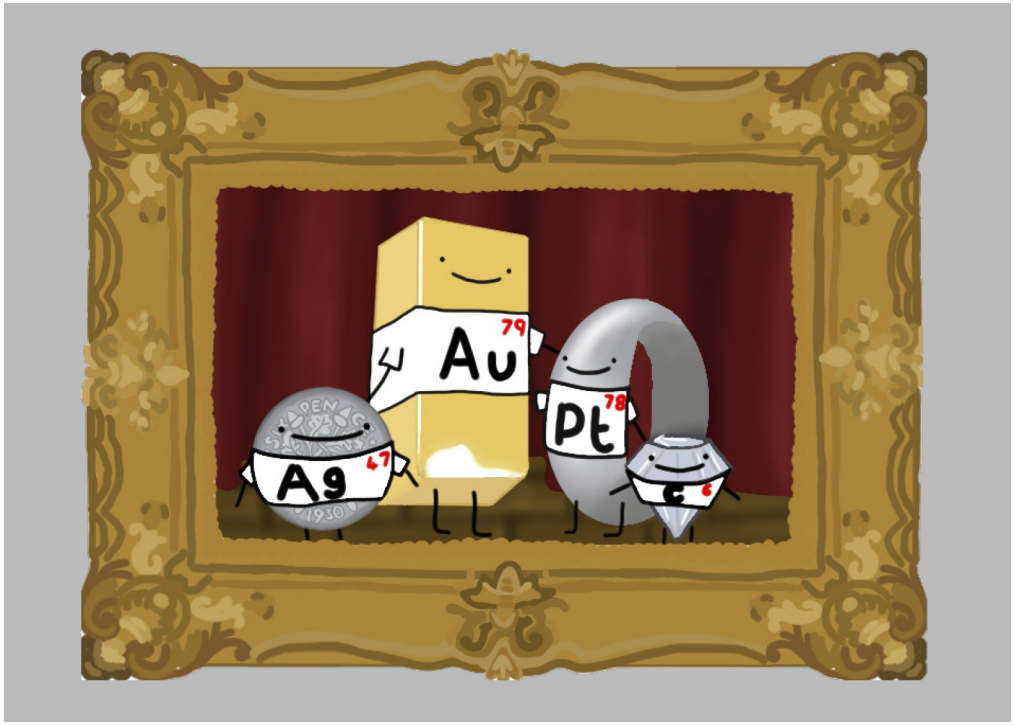
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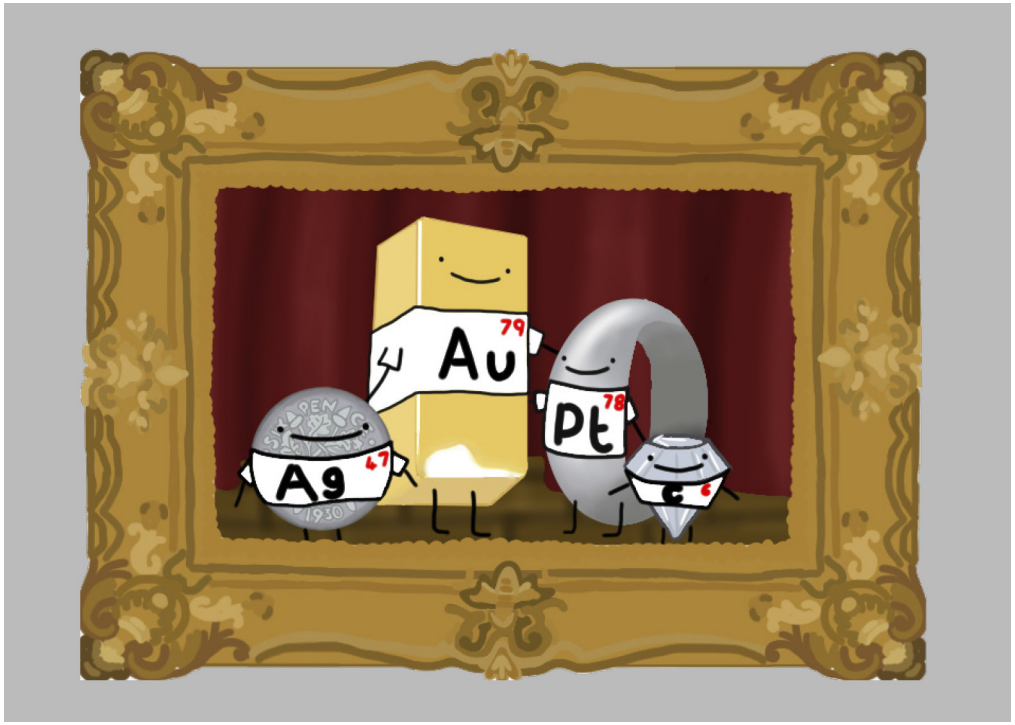
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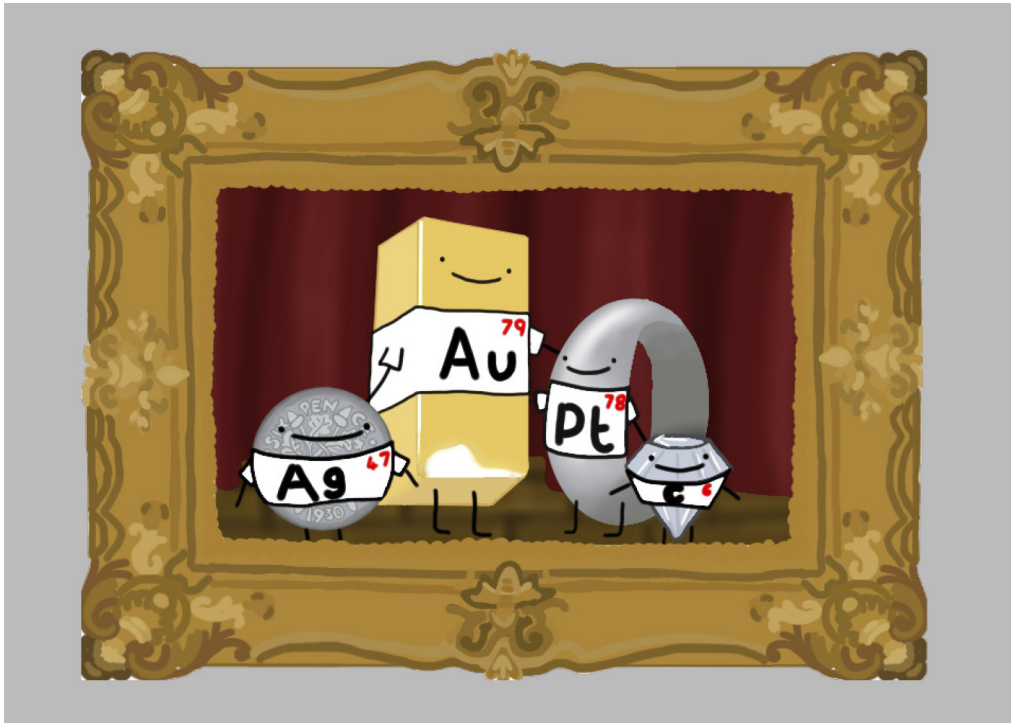
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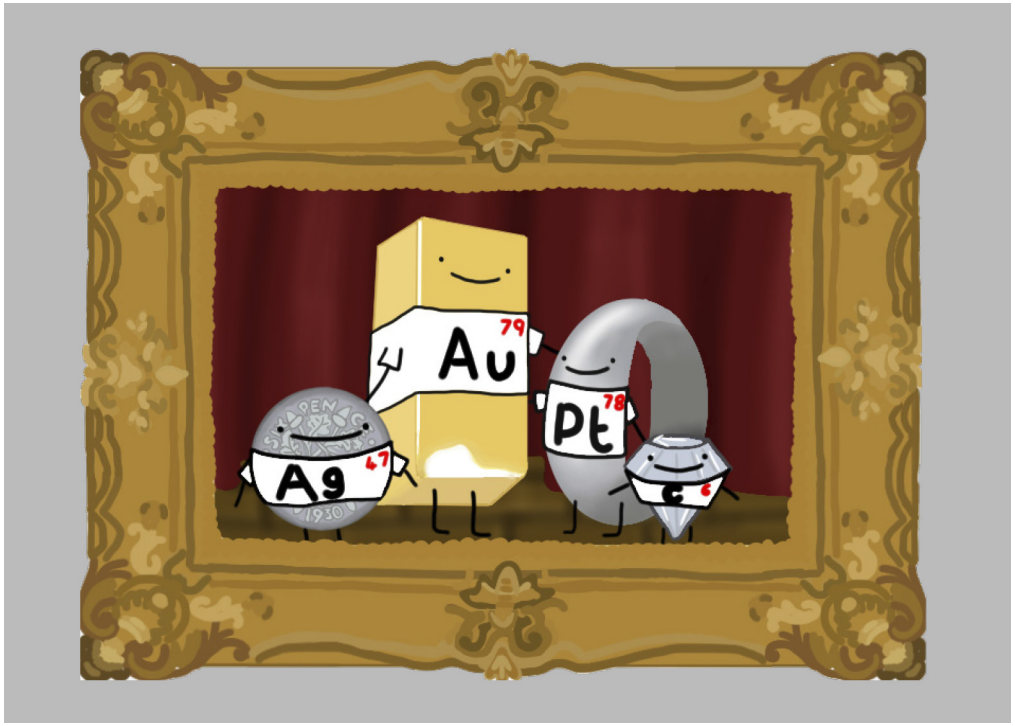
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TUNGSTEN

Elements for Lighting

W **74**

$FeWO_4$ **183.84**

Discovered by: *José and Fausto Elhuyar (Columbia)*

Discovered in: *1783*

Host Mineral: *ferberite, scheelite*

Uses: *drill-bits, light bulb filaments, X-ray tubes, electrodes in TIG welding, superalloys, radiation shielding, proectiles, catalysts*

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NEON

Elements for Lighting

Ne **10**

20.17

Discovered by: *Sir William Ramsay, Morris W. Travers (UK)*

Discovered in: *1898*

Host Mineral: *air (fraction of)*

Uses: *signs (bright reddish-orange light), vacuum tubes, high-voltage indicators, wave meter tubes, television tubes, lasers*

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CERIUM

Elements for Catalytic Converters

Ce **58**

$Ce(CO_3)F$ **140.12**

Discovered by: *Carl Gustaf Mosander (Sweden)*

Discovered in: *1839*

Host Mineral: *bastnäsite, monazite*

Uses: *glass polishing, catalytic converters*

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RHODIUM

Elements for Catalytic Converters

Rh **45**

$PtAs_2$ **102.91**

Discovered by: *William Hyde Wollaston*

Discovered in: *1803*

Host Mineral: *sperrylite*

Uses: *catalytic converters, electrical contacts, rhodium plating in components for optical instruments*

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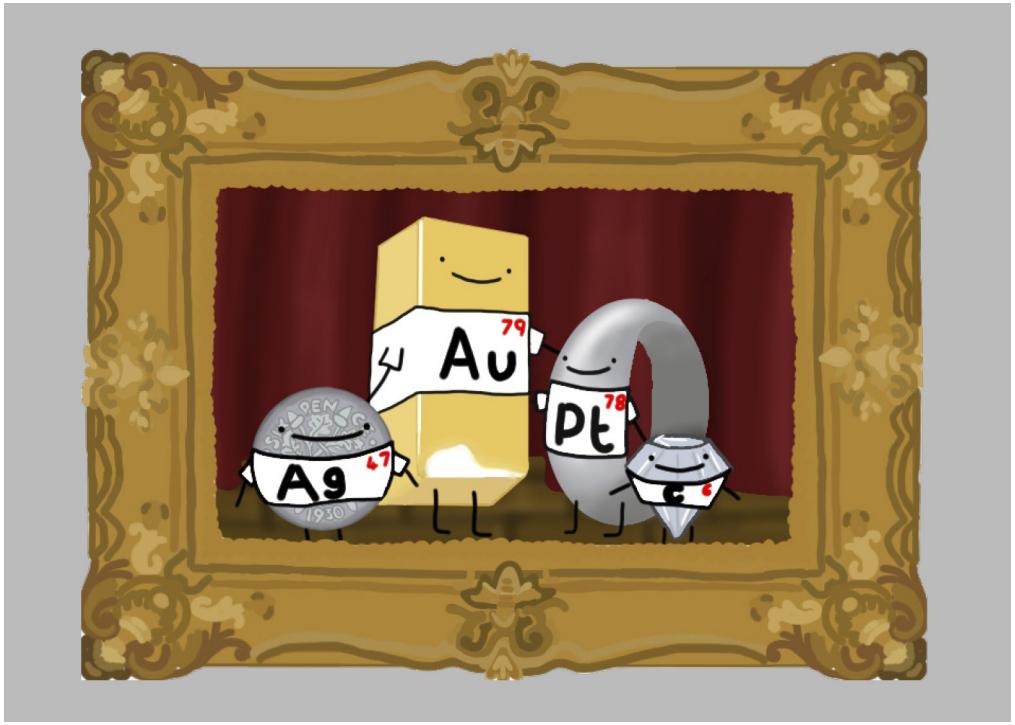
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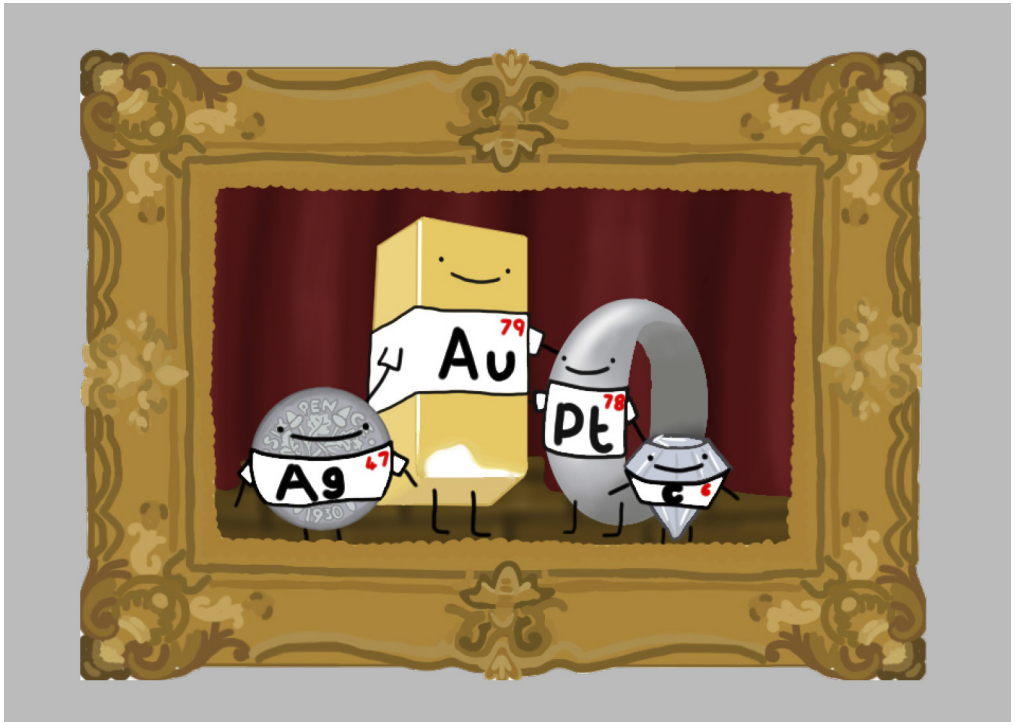
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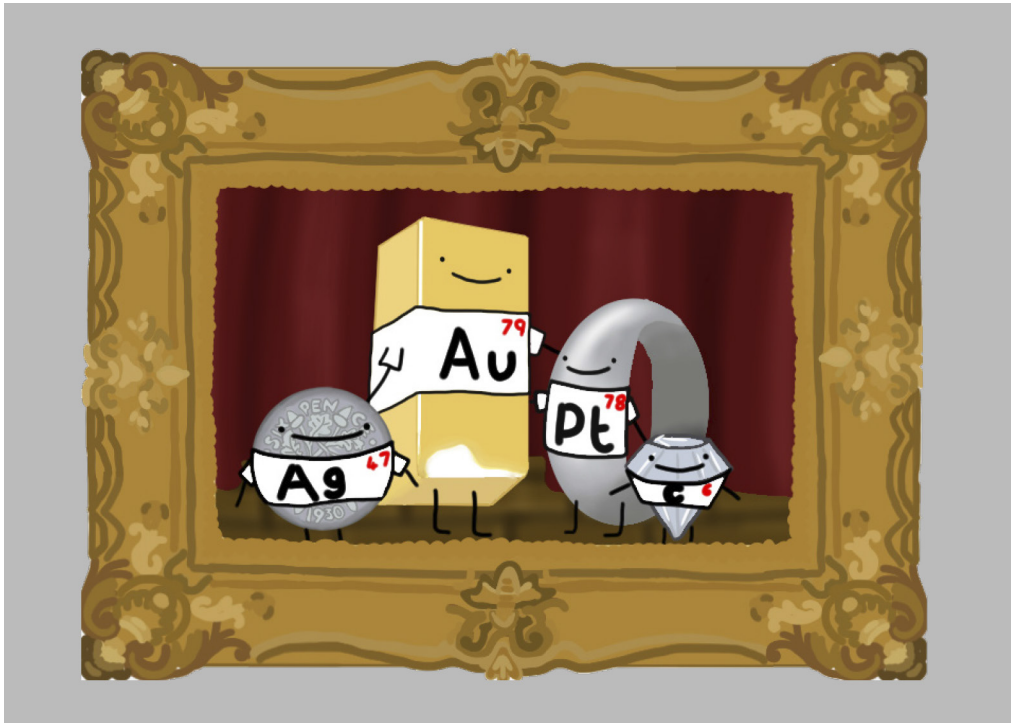
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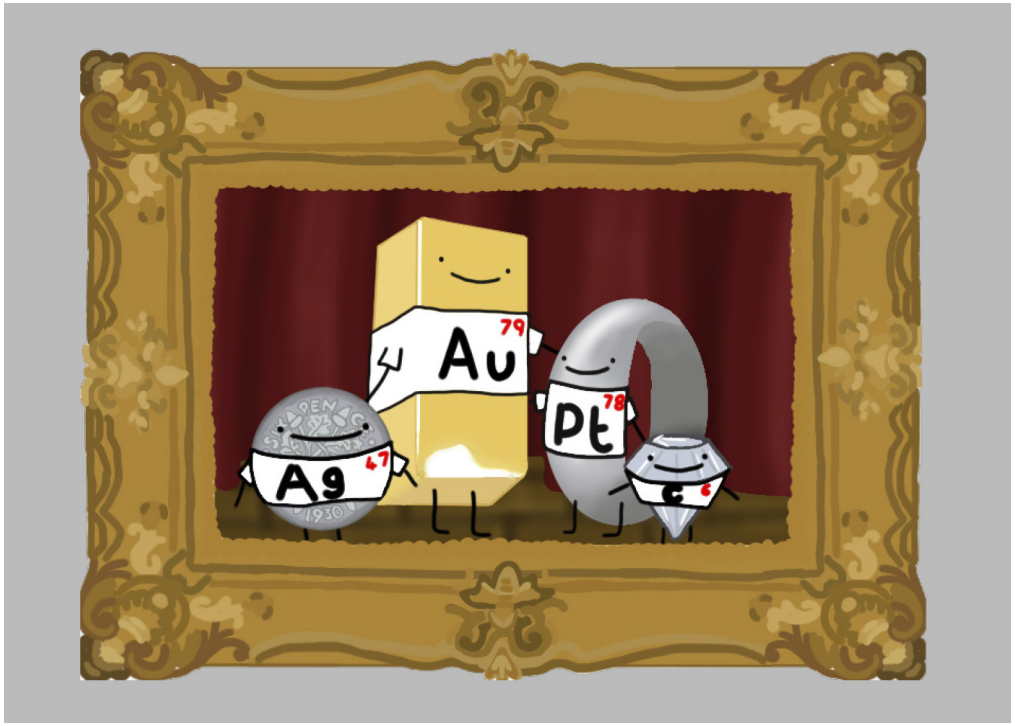
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LANTHANUM

Elements for Catalytic Converters

La **57**

$Ce(PO_4)$ **138.91**

Discovered by: *Carl Gustaf Mosander (Sweden)*

Discovered in: *1923*

Host Mineral: *monazite, bastnäsite*

Uses: *batteries, hydrogen storage alloys catalytic converters, studio lights/projectors, ignition elements, arc welding electrodes*

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PALLADIUM

Elements for Catalytic Converters

Pd **46**

$PtAs_2$ **106.42**

Discovered by: *William Hyde Wollaston (UK)*

Discovered in: *1803*

Host Mineral: *sperrylite*

Uses: *catalytic converters, electronics, technology, hydrogen storage, dentistry, jewellery, photography*

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PRASEODYMIUM

Rare Earths for Magnets

Pr **59**

$Ce(CO_3)F$ **140.91**

Discovered by: *Carl Auer von Welsbach (Sweden)*

Discovered in: *1885*

Host Mineral: *bastnäsite, monazite*

Uses: *magnets, colouring glass (green/yellow), yellow light filter*

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NEODYMIUM

Rare Earths for Magnets

Nd **60**

$Ce(PO_4)$ **144.24**

Discovered by: *Carl Auer von Welsbach (Austria)*

Discovered in: *1886*

Host Mineral: *monazite, bastnäsite*

Uses: *magnets in hybrid/electric car motors, wind turbines, glass dyes, lasers*

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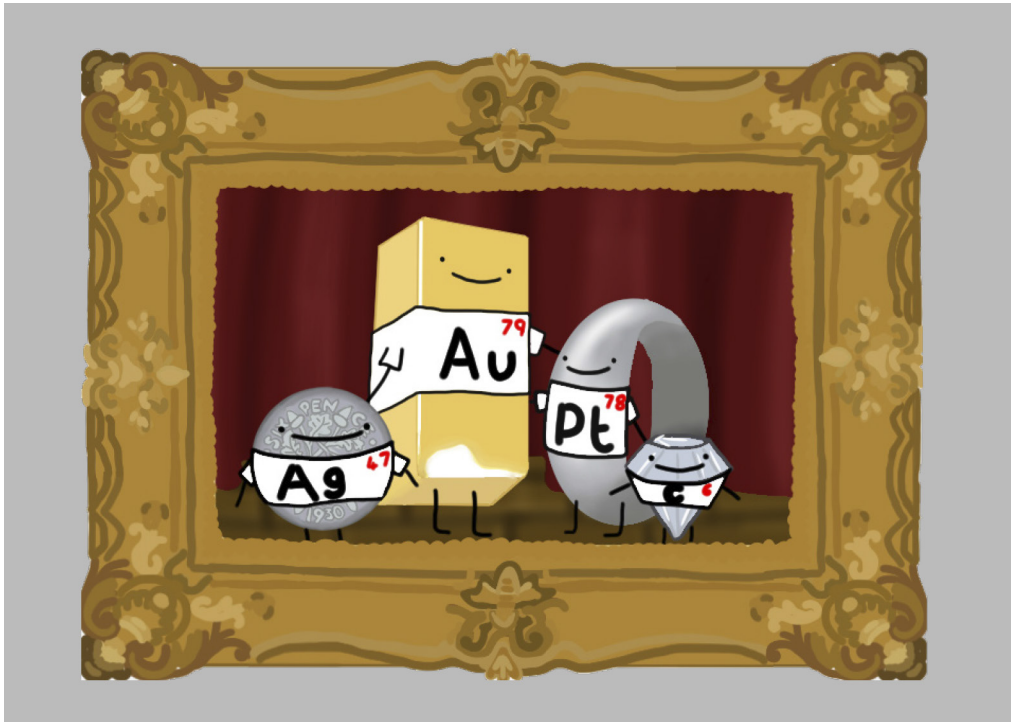
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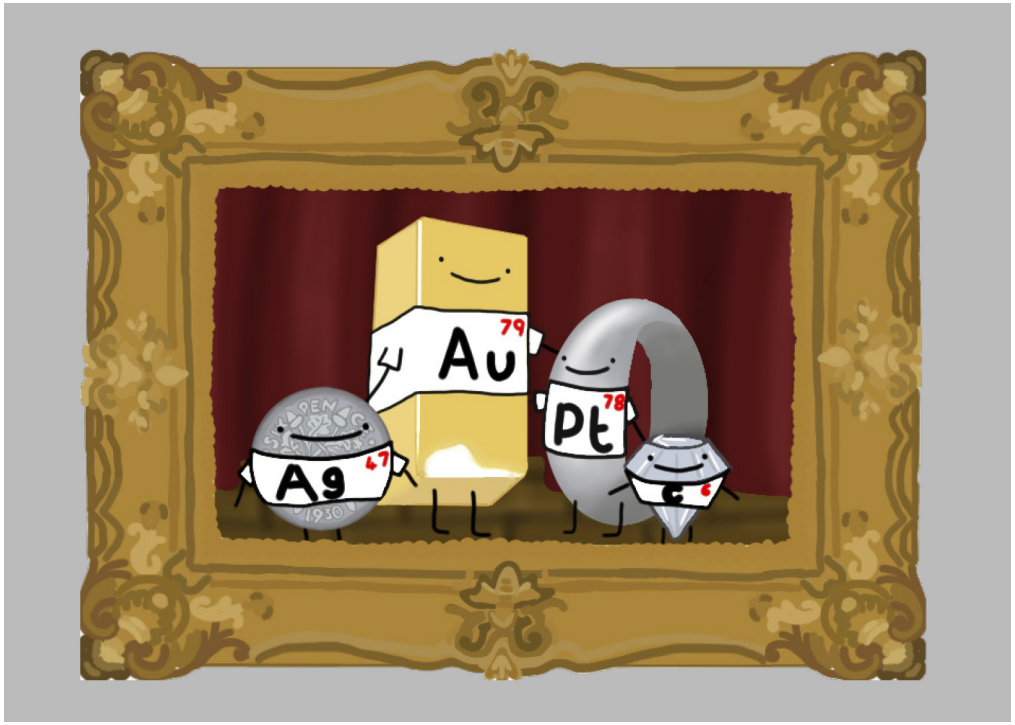
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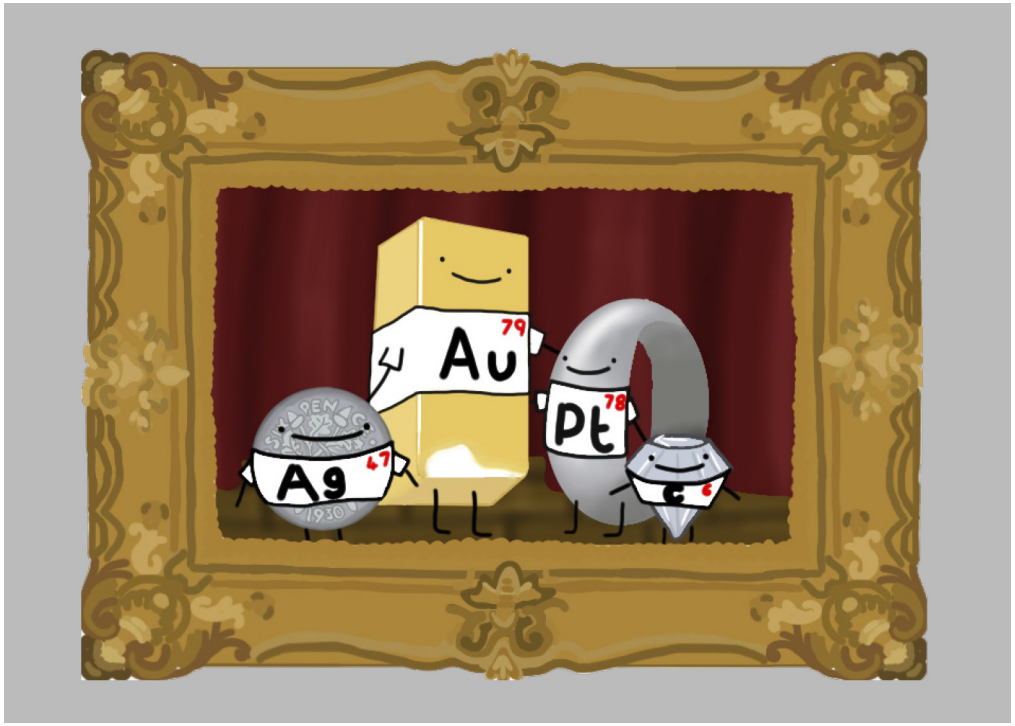
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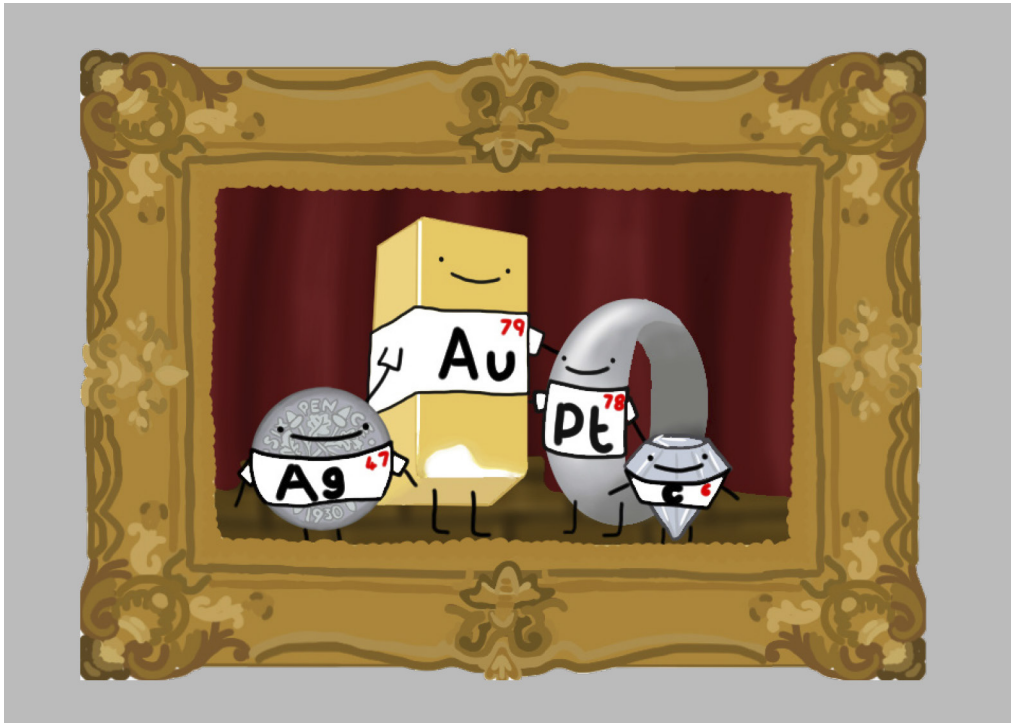
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SAMARIUM

Rare Earths for Magnets

Sm **62**

$Ce(CO_3)F$ **150.36**

Discovered by: *Paul Émile Lecoq de Boisbaudran (French)*

Discovered in: *1879*

Host Mineral: *monazite, bastnäsite*

Uses: *motorsport hybrid motors, magnets in commercial aircraft wing controllers, cancer fighting drugs, control rods of nuclear reactors, X-ray lasers*

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DYSPROSIUM

Rare Earths for Magnets

Dy **66**

YPO_4 **162.50**

Discovered by: *Paul Émile Lecoq de Boisbaudran (France)*

Discovered in: *1878*

Host Mineral: *xenotime, clays*

Uses: *wind turbines, electric and hybrid car motors, control rods in nuclear reactors, data storage applications (high magnetic susceptibility), component of Terfenol-D*

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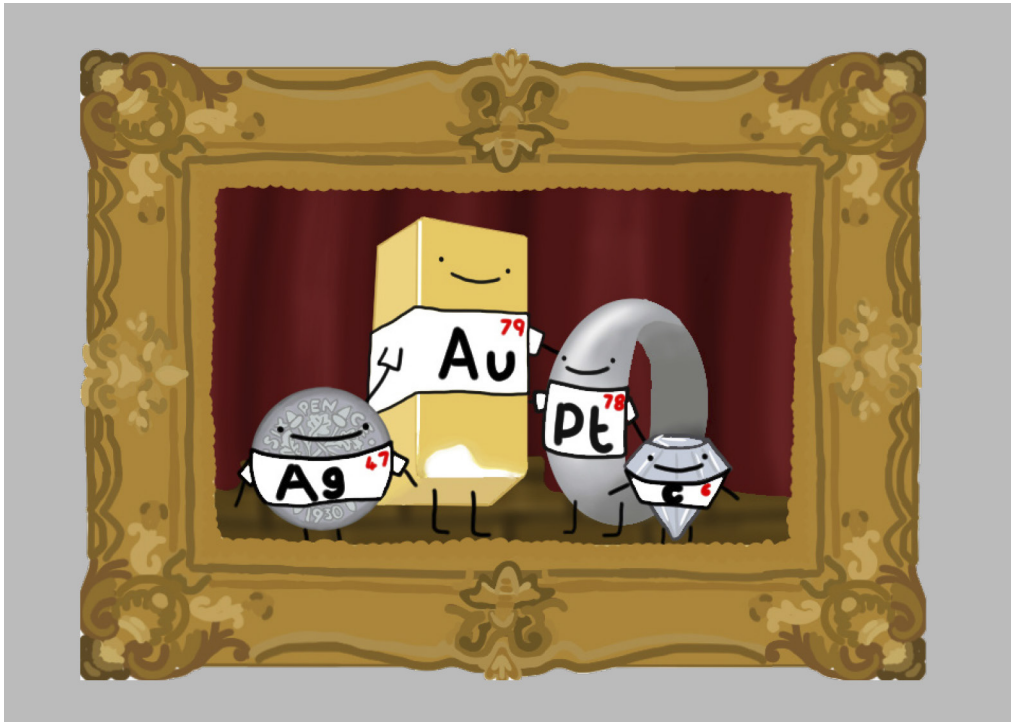
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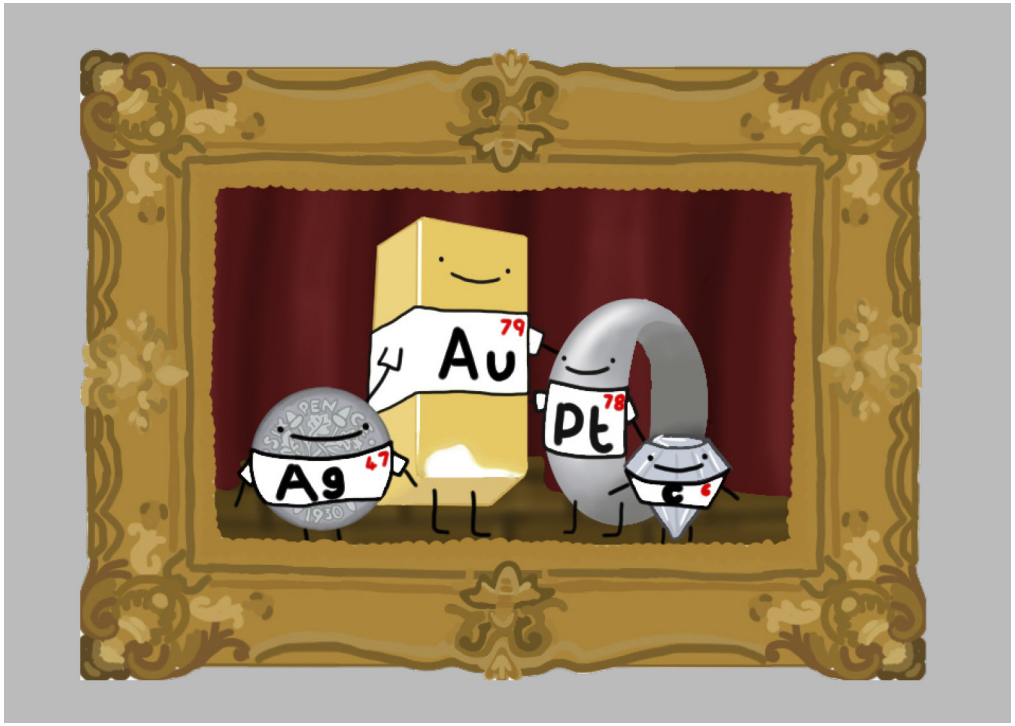
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