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, atomic number, electron arrangement 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

Shuffle 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.
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)
**Rhenium**

- **Symbol**: Re
- **Atomic Number**: 75
- **Atomic Mass**: 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

**Beryllium**

- **Symbol**: Be
- **Atomic Number**: 4
- **Atomic Mass**: 9.01
- **Discovered By**: Friedrich Wöhler (Germany) and Antoine Bussy (France)
- **Discovered In**: 1828
- **Host Mineral**: bertrandite
- **Uses**: used in super-light alloys for aerospace applications

**Scandium**

- **Symbol**: Sc
- **Atomic Number**: 21
- **Atomic Mass**: 44.96
- **Discovered By**: Fredrik Nilson (Sweden)
- **Discovered In**: 1879
- **Host Mineral**: euxenite
- **Uses**: aluminum-scandium alloys for aerospace industry, sports equipment (bicycle frames, fishing rods, baseball bats)

**Niobium**

- **Symbol**: Nb
- **Atomic Number**: 41
- **Atomic Mass**: 92.91
- **Discovered By**: Charles Hatchett (UK)
- **Discovered In**: 1801
- **Host Mineral**: pyrochlore
- **Uses**: superalloys for jet engines and heat resistant equipment, pipeline construction
**SILVER**

- **Ag**: 47
- **Ag₂S**: 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

**GOLD**

- **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

**DIAMOND**

- **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)

**PLATINUM**

- **Pt**: 78
- **PtAs₂**: 195.08

- **Discovered by**: Julius Caesar Scaliger (Italian)
- **Discovered in**: 1557
- **Host Mineral**: sperrylite, native platinum
- **Uses**: currency, jewellery, electronics, lab equipment, catalysis
**ZINC**

**Zn**

**(Zn,Fe)S**

**Mass Number** 30

**Atomic Number** 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

---

**FLUORINE**

**F**

**CaF₂**

**Mass Number** 18.99

**Discovered by:** Henri Moissan (France)

**Discovered in:** 1886 (isolated)

**Host Mineral:** fluorite

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

---

**LEAD**

**Pb**

**PbS**

**Mass Number** 82

**Atomic Number** 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

---

**IRON**

**Fe**

**Fe₂O₃**

**Mass Number** 26

**Atomic Number** 55.85

**Discovered by:** unknown

**Discovered in:** in use since ~3500 BC

**Host Mineral:** hematite, magnetite

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

Cu

CuFeS$_2$

- **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

**TANTALUM**

Ta

(Fe,Mn)Ta$_2$O$_6$

- **Discovered by:** Anders Ekeberg (Sweden)
- **Discovered in:** 1802
- **Host Mineral:** tantalite
- **Uses:** electronic equipment, as a substitute for platinum

**TIN**

Sn

SnO$_2$

- **Discovered by:** unknown
- **Discovered in:** Bronze Age
- **Host Mineral:** cassiterite
- **Uses:** lead-free solder, electronics, tin plating (prevents corrosion), glass making, Li-ion batteries

**INDIUM**

In

(Zn,Fe)S

- **Discovered by:** Ferdinand Reich and Hieronymus Theodor Richter (Germany)
- **Discovered in:** 1863
- **Host Mineral:** sphalerite
- **Uses:** touch screen technology in mobile phones, semiconductors, high vacuum seals, batteries, as a stabiliser
<table>
<thead>
<tr>
<th>Element</th>
<th>Atomic Number</th>
<th>Uses</th>
<th>Host Mineral</th>
<th>Discoverer</th>
<th>Discovery Year</th>
</tr>
</thead>
<tbody>
<tr>
<td>LITHIUM</td>
<td>3</td>
<td>batteries, ceramics and glass, electronics, lubricating grease, various medical uses</td>
<td>spodumene, petalite, brines</td>
<td>Johan August Arfwedson</td>
<td>1817</td>
</tr>
<tr>
<td>CARBON</td>
<td>6</td>
<td>(graphite) electrode in Li batteries, pencils, charcoal, cloth, steel, carbon fibre, printing ink</td>
<td>graphite</td>
<td>Carl Wilhelm Scheele</td>
<td>1779</td>
</tr>
<tr>
<td>COBALT</td>
<td>27</td>
<td>electrode in Li batteries, alloys, catalysts, pigments and colouring, radioisotopes</td>
<td>heterogenite, cobaltite</td>
<td>Georg Brandt</td>
<td>1735</td>
</tr>
<tr>
<td>NICKEL</td>
<td>28</td>
<td>NiMH (Nickel Metal Hydride) batteries, magnets, electric guitar strings, microphone capsules, plating on plumbing fixtures</td>
<td>pentlandite, garnierite</td>
<td>Baron Axel Fredrik Cronstedt</td>
<td>1751</td>
</tr>
</tbody>
</table>
**SILICON**

- **Si**
- **14**
- **SiO₂**
- **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)

**Selenium**

- **Se**
- **34**
- **CuFeS₂**
- **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

**Tellurium**

- **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)

**Gallium**

- **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
**YTTRIUM**

**Y**

YPO₄

39

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

---

**EUROPIUM**

**Eu**

Ce(CO₃)F

63

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

---

**TUNGSTEN**

**W**

FeWO₄

74

183.84

**DISCOVERED BY:** José and Fausto Elhuyar (Spain)

**DISCOVERED IN:** 1783

**HOST MINERAL:** ferberite, scheelite

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

---

**NEON**

**Ne**

20.17

10

**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
CERIUM

**Ce**

Ce(CO₃)F

**58**

**140.12**

- **Discovered by:** Carl Gustaf Mosander (Sweden)
- **Discovered in:** 1839
- **Host Mineral:** bastnäsite, monazite
- **Uses:** glass polishing, catalytic converters

RHODIUM

**Rh**

PtAs₂

**45**

**102.91**

- **Discovered by:** William Hyde Wollaston (UK)
- **Discovered in:** 1803
- **Host Mineral:** sperrylite
- **Uses:** catalytic converters, electrical contacts, rhodium plating in components for optical instruments

LANTHANUM

**La**

Ce(PO₄)

**57**

**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

PALLADIUM

**Pd**

PtAs₂

**46**

**106.42**

- **Discovered by:** William Hyde Wollaston (UK)
- **Discovered in:** 1803
- **Host Mineral:** sperrylite
- **Uses:** catalytic converters, electronics, technology, hydrogen storage, dentistry, jewellery, photography
<table>
<thead>
<tr>
<th>Element</th>
<th>Atomic Number</th>
<th>Mass Number</th>
<th>Discovery Details</th>
<th>Uses</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Praseodymium</strong></td>
<td>59</td>
<td>140.91</td>
<td></td>
<td>magnets, colouring glass (green/yellow), yellow light filter</td>
</tr>
<tr>
<td><strong>Neodymium</strong></td>
<td>60</td>
<td>144.24</td>
<td></td>
<td>magnets in hybrid/electric car motors, wind turbines, glass dyes, lasers</td>
</tr>
<tr>
<td><strong>Samarium</strong></td>
<td>62</td>
<td>150.36</td>
<td></td>
<td>motorsport hybrid motors, magnets in commercial aircraft wing controllers, cancer fighting drugs, control rods of nuclear reactors, X-ray lasers</td>
</tr>
<tr>
<td><strong>Dysprosium</strong></td>
<td>66</td>
<td>162.50</td>
<td></td>
<td>wind turbines, electric and hybrid car motors, control rods in nuclear reactors, data storage applications (high magnetic susceptibility), component of Terfenol-D</td>
</tr>
</tbody>
</table>