The Chemical Elements and Periodic Table

At a glance

	Content summary	National Curriculum links	Activities
Lesson 1	Students' prior knowledge of chemical elements; how some elements were discovered	Particle theory; pure / impure substances; scientific terminology; working scientifically	**Activity A:** Element Bingo! **Activity B:** How were the chemical elements discovered?
Lesson 2	How chemical elements were organised leading to our current periodic table	Working scientifically; scientific knowledge explains natural phenomena	**Activity C:** How did the periodic table develop?

Background and National Curriculum links

These activities are intended for two lessons for Year 7-9 students on the periodic table. The activities offer opportunities to investigate the history of the periodic table.

Lesson 1

Lesson 1 starts with an activity to probe students' prior knowledge of the chemical elements. This can be extended and developed as required. Element names and symbols are introduced. Next students work in teams to investigate how chemical elements were discovered. They present their findings and undertake peer assessment.

National Curriculum

- Developing students' scientific vocabulary and terminology in relation to chemistry;
- The varying physical and chemical properties of different elements.

Lesson 2

In lesson 2 students find out how the periodic table was developed. A historically-based resource is provided showing how scientists' ideas about the chemical elements and how to organise them have changed over time. Mendeleev's periodic table is introduced. As an extension activity, students can find out about the composition of the Earth and the scarcity of some elements on which we depend.

National Curriculum

- Principles underpinning the Mendeelev periodic table;
- The composition of the Earth;
- Earth as a source of limited resources.

Teacher subject knowledge

- Teachers need good understanding of the structure of the periodic table.
- Knowledge of its origins and development is helpful, together with knowledge of group and periodic trends in the chemical and physical characteristics of chemical elements.

Cross-curricular links

From the eighteenth century onwards, new chemical techniques including spectroscopy helped scientists discover substances identified as 'chemical elements'. 92 chemical elements occur naturally in the Earth's crust and atmosphere, numbered from atomic number 1 (H, hydrogen) to 92 (U, uranium). In the 20th and 21st centuries, 'atom smashers' called cyclotrons were developed by international teams of scientists. Their experiments have resulted in 26 synthetic 'super-heavy' elements.

Rather than regarding them as random substances, chemists sought to organise elements systematically based on similarities in chemical and physical properties. Scientists including John Dalton, Humphrey Davy, John Newlands, Antoine and Marie-Anne Lavoisier and Johann Döbereiner contributed new elements and/or ways of thinking about how to organise chemical elements. In the mid-nineteenth century, the Russian chemist Dimitri Mendeleev ordered all known chemical elements by atomic mass, knowing that mass values of some elements were inaccurate, and guessing that further elements would be discovered. He placed elements with similar properties in columns and left gaps for new elements. He published his periodic table in 1869. This laid the foundations for the periodic table we know today.

The periodic table represents a common language for science, is a product of international scientific research effort, and uses symbols and data known globally. The periodic table is relevant to current global trends and perspectives on sustainable development, particularly responsible use of the Earth's resources. The topic links to physics, medicine and Earth science and permits discussion of international relations from the perspective of global scientific research.

Student background knowledge

Students should know the differences between chemical elements, compounds and mixtures. Prior awareness of the periodic table is helpful.

Resources and timing

One or two 50 – 60 minute lessons are required.

Technical requirements

No laboratory equipment is required.

Lesson 1

Activity A: Element bingo - Introducing the chemical elements

This task is designed to probe students' prior knowledge.

Each individual / pair of students will need the 'Element bingo' sheet.

A small prize can be provided for the winner.

Without reading the corresponding numbers, clues are read out in a random order by the teacher (or a student). Students write down the name of the element they think is represented by the image and cross off the clue. 12 elements are provided, some likely to be well known (e.g. oxygen, iron) others less so (e.g. phosphorus, radium).

The first student to correctly identify and name all elements in one horizontal or vertical row is declared the winner, with bonus points (or an extra prize) if they know symbols for the elements.

Identifying the elements calcium, iron, radium and silicon from each other may be difficult. This illustrates that many solid elements have similar appearances.

Once all the elements have been identified, find out:

- If students know anything more about these elements;
- What other chemical elements they have heard of. Examples may be: silver, nitrogen, aluminium, platinum, sulfur, zinc, mercury.

Students may think that:

- alloys such as steel (carbon/iron), brass (copper/zinc) and bronze (copper / tin / aluminium) are elements. These are mixtures of metals and non-metals.
- Earth, wind, fire and water are elements – this ancient Greek view is not accepted as true today.

Clue	Name	Symbol	Image No.
This element, shown as a blue liquid, makes up about 20% of the Earth's atmosphere.	Oxygen	O	1
This gas glows orange-red in lighting and is not chemically reactive.	Neon	Ne	2
We use this element every day. It's also found in expensive jewellery.	Carbon	C	3
The 5th most common element in the body, this metal is found in compounds in rocks.	Calcium	Ca	4
A yellow-coloured metal mined in its 'native' (unreacted) form.	Gold	Au	5
A yellow-green toxic gas – useful in swimming pools!	Chlorine	Cl	6
An extremely useful metal mined and used since 3000BCE.	Iron	Fe	7
A radioactive element discovered by Marie Curie in 1898.	Radium	Ra	8
A semi-conductor used in computers, the 2nd most abundant element in the Earth's crust.	Silicon	Si	9
The 2nd lightest element, it is named after the Sun, where it was first found.	Helium	He	10
This element, required for all forms of life, is found reacted with oxygen in every living cell.	Phosphorus	P	11
An excellent conductor of heat and electricity, this orange-red element turns green in air.	Copper	Cu	12

Activity B: How were the chemical elements discovered?

Each pair or group of students will need:

- A copy of the student version of the table 'How were the chemical elements discovered?'
- Access to the internet for research
- Access to large sheets of sugar paper, A4 paper and pens
- Display space

A completed version of the table is provided for reference. Note that only a sample of chemical elements is included in the table. Those included are suggestions only. The resource can be amended as necessary to suit students of different abilities and varying class sizes. Extensive further information is available via the internet. Use the resource to

provide introductory information and to summarise once students have completed their research.

The resource lists 7 'Ages of Discovery'. The resource is provided in two versions:

- Complete – this version is intended to act as a reference source. The task can be adapted for a wide ability range by asking students to find information of varying levels of detail. It is not expected that all students would find the level of detail shown.
- With element names only – to be given to students to complete.

Class organisation

Divide the class into 7 groups, each group investigating elements found in one Age of Discovery. In a class of 30 this gives about 4 students for each Age of Discovery. Each student can work on one (or more) elements; pairs of students could research two or three elements together. One student can be responsible for ensuring that a range of elements is investigated in each Age of Discovery. They can report back to the whole class.

Research

Each student / pair / group of students should research information about one or more of the chemical elements in their Age of Discovery. The level of detail can be altered depending on students' abilities. As a minimum for each element, find out:

- Discovery date, or date when it became known;
- Appearance, physical state, colour, shininess;
- Who discovered it, or how it was first known, the nationality of the scientist / country where it was discovered;
- How the element has been used / why it is important today.

Additional aspects:

- Any special chemical / physical properties associated with its use, for example, silicon is a semi-conductor; gold is a 'precious' metal because it is available in small quantities only and doesn't tarnish over many years; oxygen is needed for life on Earth to be sustained;
- If the element is rare or abundant;
- If any special historic events occurred in the Age of Discovery;
- If any famous scientific discoveries were made in the Age of Discovery.

Presentation

Ask each group representing the seven Ages of Discovery to prepare one or more posters to summarise their research. Then:

- Display the posters;
- Allow groups to read information presented by the other groups;
- Peer assess the posters using stated criteria, for example:
  - Is the minimum information provided for each element? (see list above)
  - How clearly is the information communicated?
  - Has the group given any other relevant information about the elements?

Whole class discussion

The posters should show information similar to that provided in the complete version of the resource. Questions to support the discussion are provided. These (or a selection) could be answered by each group in advance, for whole class discussion.

- How many different nationalities are represented in the scientists who discovered the elements? What does this tell us about the periodic table and the chemical elements?
  - To answer this question, count the number of nations mentioned on the posters.
  - The periodic table represents the work of scientists worldwide.
- Why were so few women involved in discovering new chemical elements?
  - In many societies, women had few social and economic rights. They were not encouraged to work as scientists. Marie Curie was a notable exception. Others, such as Anne-Marie Paulze Lavoisier made significant contributions but traditions and social expectations at the time meant that they were not noticed.
- Some elements were 'discovered' by one person, but 'isolated' by others – what does this mean?
  - One scientist noticed that there may be a new element present, so 'discovered' it, but was unable to obtain a sample. Another scientist was able to obtain a sample of the element, 'isolating' it from a mineral ore, or a mixture of other elements.
- How did new scientific techniques help discovery of chemical elements?
  - Early techniques involved trial and error, heating mineral ores and finding samples of native metals. From about 1700 onwards, economies became wealthier, leading to glassware, weighing and heating apparatuses. The Industrial Revolution improved heating techniques and led to electricity becoming available. Spectroscopy gave insights into the structure of substances. Atomic structure was a focus from 1900 onwards, leading to radioactivity being characterised, together with sub-atomic particles. The Manhattan project led to the development of atomic bombs. Post-war, cyclotrons became increasingly powerful, leading to discovery of the heavy and super-heavy elements.

- How did scientists communicate their discoveries?
  - Organisations such as the Royal Society (founded in 1660) arranged meetings so that scientists could transfer information between them. This tradition continues today. Scientists wrote letters to each other and made visits. In the ancient world, oral information was exchanged and written down.
- Which major historical events have impacted discoveries?
  - World wars interrupted international collaborations but also led to new technological developments.
- Do they think that further elements will be discovered? If so why, if not why not?
  - It is possible that more elements will be discovered, but these experiments are expensive and require extensive collaborative effort.
  - The 7th line (period) of the periodic table is now complete. Scientists think that it would be very challenging to start a new period of super-heavy elements.

Extensions

Follow up on the discovery of the most recently added super-heavy chemical elements. An article is available at: https://pls.llnl.gov/research-and-development/nuclear-science/project-highlights/livermorium/elements-113-and-115. This article could form the basis for a directed activity related to text about how the discoveries were made.

A timeline of chemical element discoveries is available at: https://en.wikipedia.org/wiki/Timeline_of_chemical_element_discoveries#cite_note-10.

Lesson 2

Activity C: How did the periodic table develop?

The resource shows images associated with ways that philosophers and scientists organised substances that they believed to be chemical elements.

Use the resource to provide introductory material for this activity.

Each pair / group of students will need:

- Access to the resource
- Access to the internet
- A method of presenting to the class

Divide the class into seven groups. Give one image to each group. Ask each group to:

- Research the image – who proposed it? What does it represent? Why were the elements thought about in this way?
- What evidence was used to create the representation? Does any of this evidence hold true today? If so, which?
- Ask students to find out which substances are now known to be compounds or mixtures rather than chemical elements.

Ask each group to prepare a presentation about their version of the representation of the chemical elements using the questions above as a guide.

- Ensure that groups introduce their representation.
- Ask groups to present in historical order.

Discuss:

- Are any features common to all the images? What are these?
- What led scientists / philosophers to change their ideas at each stage?
- Why has Mendeleev's version lasted compared to the others?

Extensions

A periodic table showing the chemical elements by their abundance is available at: https://www.livescience.com/64596-new-periodic-table-shows-helium-scarcity.html

Some chemical elements are in short supply. Most of these are the rare earth elements (Scandium, Yttrium, Lanthanum and Cerium to Lutetium). We rely on these elements in solar panels, mobile phones, medical equipment and computers. How do we use yet care for the Earth's resources? Relevant articles include:

- Elements in short supply | Nature Materials
- SMM: supply is tight downstream demand is expected to push rare Earth prices stronger in 2021 [rare Earth permanent Magnet Conference]_SMM | Shanghai Non ferrous Metals

Activity A: 'Element Bingo'

1. Chemical Element Pictures - Photo Gallery (thoughtco.com)
2. Open Sign Signage - Free photo on Pixabay
3. Carbon image - Bing images
4. Calcium - Wikimedia Commons
5. Image of nugget of gold creative commons - Bing images
6. Swimming Photos - FREE Creative Commons Photos of Swimming (photosforclass.com)
7. Image of pure iron metal creative commons - Bing images
8. Radium - Wikipedia
9. Category:Silicon - Wikimedia Commons
10. Helium - Bing images
11. skelett.jpg (800×564) (medicalgraphics.de)
12. Copper - Bing images

Activity B: How were the chemical elements discovered? Version 1: Completed

Age of discovery	Element	Picture of the element	Atomic number	Date of discovery / earliest known use	Scientist(s) / place	Method
Antiquity	Copper		29	9000BCE	Middle East and Anatolia (Turkey)	Obtained as a native metal, then smelted from ores
	Gold		79	Before 6000BCE	Levant (Israel, Lebanon and Syria)	Obtained as a native metal
	Iron		26	Before 5000BCE	Middle East	The oldest iron objects date from around 5000BC. Smelting was discovered in around 3000BC, leading to the Iron Age
	Carbon Graphite Diamond Graphene		6	 Around 3750BCE Around 2500BCE 2004	 Egyptians and Sumerians Andre Geim and Konstantin Novoselov	Charcoal was used in smelting metal ores to produce copper, tin and zinc Graphene was known from about 1948 but only finally produced in 2004
Middle Ages – 1799	Phosphorus		15	1669	Hennig Brand, Germany	Isolated from urine
	Oxygen		8	1771	Wilhem Scheele, Sweden and Joseph Priestley, England	From heating mercury(II) oxide and, separately, nitrates
	Nitrogen		7	1772	Daniel Rutherford, Scotland	By showing that air in which animals had breathed would not support a candle burning, even after removal of carbon dioxide
	Platinum		78	1735	Antonio de Ulloa y de la Torre-Giral, Spain	Found in South American gold
Industrial revolution 1800 – 1849	Aluminium		13	1825	Hans Christian Ørsted, Denmark	Isolated from aluminium oxide
	Potassium		19	1807	Humphry Davy, England	Electrolysis of potash (potassium hydroxide)
	Cadmium		48	1817	Karl Samuel Lerberecht Hermann, Germany, Frederick Stromeyer, Germany and Johann Christian Heinrich Roloff, Germany	Found independently in zinc oxide
	Iodine		53	1811	Bernard Courtois, France	Discovered in the ashes of seaweed

Activity B: How were the chemical elements discovered? Version 1: Completed cont.

Age of discovery	Element	Picture of the element	Atomic number	Date of discovery / earliest known use	Scientist(s) / place	Method
Post-industrial revolution 1850 – 1899	Caesium		55	1860	Robert Wilhelm Eberhard Bunsen, Germany and Gustav Robert Kirchhoff, Germany	Spectroscopy was used for the first time to discover an element. Blue lines in the spectrum from a sample of mineral water from Dürkheim were from caesium. The metal was isolated a few years later
	Helium		2	1868	Pierre Jules César Janssen, France and Joseph Norman Lockyer, England	Using spectroscopy, Janssen and Lockyer independently observed an unknown yellow line in the solar spectrum
	Rubidium		37	1861	Robert Wilhelm Eberhard Bunsen, Germany and Gustav Robert Kirchhoff, Germany	Discovered from spectral lines in lepidolite, a rose-lilac or grey mineral containing various metals including lithium
	Thallium		81	1862	William Crookes, England	A spectroscopic discovery based on a green line in a sample of selenium. Thallium metal was isolated a few months later
	Argon		18	1894	William Ramsay, Scotland and John William Strutt, Lord Rayleigh, England	The observation that masses of nitrogen gas from liquefied air and pure nitrogen are different led to the discovery of argon in air
	Krypton		36	1898		Krypton was separated from liquid argon on the basis of its different boiling point
	Polonium		84	1898	Marie Curie, Poland and Pierre Curie, working together in France	A higher level of radioactivity was noted in a sample of pitchblende, a mineral containing uranium. The Curies proposed that this was due to a new element
	Radium		88	1898		The Curies' experiments on pitchblende led to another new element in the same mineral

Activity B: How were the chemical elements discovered? Version 1: Completed cont.

Age of discovery	Element	Picture of the element	Atomic number	Date of discovery earliest known use913	Scientist(s) / place	Method
1900 – 1949 Development of the first trans-uranium elements	Protactinium		91	1922	Oswald Helmut Göhring, Germany and Kasimir Fajans, Germany	Mendeleev predicted this element in 1871. The element is produced when ^{238}U undergoes radioactive decay. Göhring and Fajans obtained the first sample of protactinium
	Hafnium		72	1937	Dirk Coster, Netherlands and George Charles de Hevesy, Hungary	Scientists reported before WW1 that this element may exist. Post- war, it was found by X-ray spectroscopic analysis of Norwegian zircon. Hafnium was the last non-radioactive element discovered
	Technetium		43	1940	Carlo Perrier, Italy and Emilio Segrè, Italy	Found in a molybdenum sample in a cyclotron. Technetium was the first element discovered using a synthetic technique
	Neptunium		93	1940	Edwin Mattison Macmillan, USA and Philip Hauge Abelson, USA	Obtained by irradiating uranium atoms with neutrons. Neptunium was the first trans-uranium element to be discovered
	Astatine		85	1940 – 1941	Emilio Segrè, Italy, Dale Raymond Corson, USA & Kenneth Ross MacKenzie, USA	Obtained by bombarding bismuth atoms with alpha particles
	Plutonium		94	1952	Glenn Theodore Seaborg, USA, Arthur Charles Wahl, USA and Joseph William Kennedy, USA	Obtained by bombarding uranium atoms with deuterons
1950 – 1999 Post World War II	Einsteinium Fermium		99 100	1952	Albert Ghiorso and colleagues , USA	Formed in the first thermonuclear explosion by irradiating uranium atoms with neutrons. The experiment was kept secret for several years.

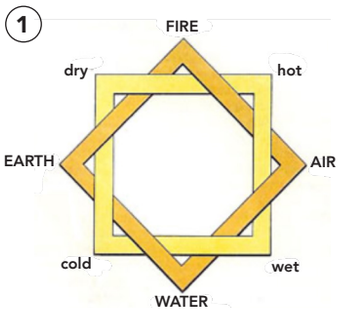
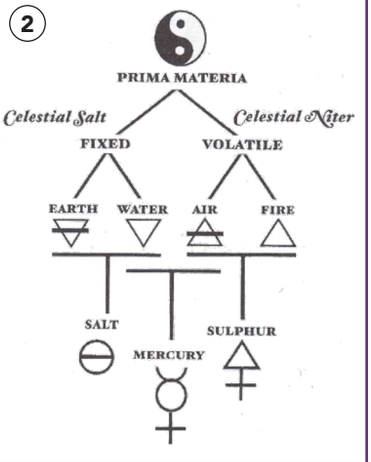
Activity B: How were the chemical elements discovered? Version 1: Completed cont.

Age of discovery	Element	Picture of the element	Atomic number	Date of discovery / earliest known use	Scientist(s) / place	Method
Production of heavier radioactive elements	Rutherfordium		104	1969	Albert Ghiorso and colleagues, USA and Ivo Josephovich Zvara, USSR	Formed by bombarding californium atoms with carbon atoms (Ghiorso's team) and plutonium atoms with neon atoms (Zvara's team)
	Dubnium		105	1970	Albert Ghiorso and colleagues, USA and V.A. Druin, USSR	Formed by bombarding californium atoms with nitrogen atoms (Ghiorso's team) and americium atoms with neon atoms (Druin's team)
2000 – present Discovery of the super-heavy elements (SHEs)	Nihonium		113	2003 – 2004	Yuri Tsolakovich Oganessian and colleagues, Russia and Kosuke Morita and colleagues, Japan	Prepared from radioactive decay of muscovium (Oganessian's team) and bombarding bismuth atoms with zinc atoms (Morita's team)
	Moscovium		115	2003	Yuri Tsolakovich Oganessian and colleagues, Russia	Formed by bombarding americium with calcium atoms
	Livermorium		116	2000	Yuri Tsolakovich Oganessian and colleagues, Russia & Ken Moody and colleagues, USA	Formed by bombarding curium atoms with calcium atoms
	Tennessine		117	2009	Yuri Tsolakovich Oganessian and colleagues, Russia	Formed by bombarding berkelium atoms with calcium atoms
	Oganesson		118	2002	Yuri Tsolakovich Oganessian and colleagues, Russia	Formed by bombarding americium atoms with calcium atoms

Activity B: How were the chemical elements discovered? Version 2: Blank

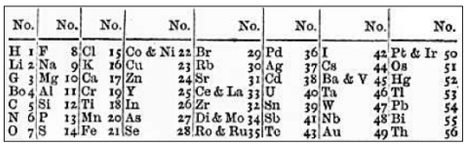
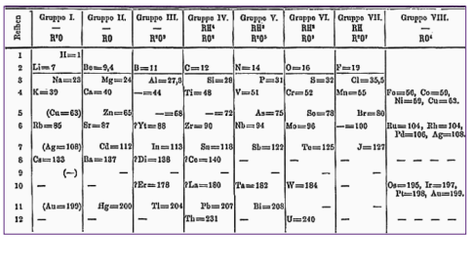
Age of discovery	Element	Picture of the element	Atomic number	Date of discovery / earliest known use	Scientist(s) / place	Method
Antiquity	Copper					
	Gold					
	Iron					
	Carbon Graphite Diamond Graphene					
Middle Ages – 1799	Phosphorus					
	Oxygen					
	Nitrogen					
	Platinum					
Industrial revolution 1800 – 1849	Aluminium					
	Potassium					
	Cadmium					
	Iodine					
Post-industrial revolution 1850 - 1899	Helium					
	Rubidium					
	Thallium					
	Argon					
1900 – 1949 First synthetic elements	Protactinium					
	Hafnium					
	Astatine					
	Plutonium					
1950 – 2000 Heavier synthetic elements	Einsteinium					
	Fermium					
	Rutherfordium					
	Dubnium					
2001 – present Super-Heavy elements	Nihonium					
	Moscovium					
	Livermorium					
	Oganesson					

Activity C: How did the periodic table develop? Complete Version

Date	Scientist	Image	Notes
Approx 350BCE	Aristotle	1 	Aristotle believed that Earth, air, fire and water are the building blocks of all substances.
1520	Paracelsus	2 	Aristotle's elements were abandoned. Paracelsus developed the idea that medicines comprise salt, mercury and sulfur, the 'tria prima'.
1789	Antoine Lavoisier	3 	Lavoisier identified sulfur as a chemical element, named oxygen and described the difference between an element and a compound. He abandoned the 'tria prima' and wrote the first list of chemical elements.

1. aristotle chemical elements image - Bing images
2. paracelsus prima materia image - Bing images
3. lavoisier chemical elements image - Bing images

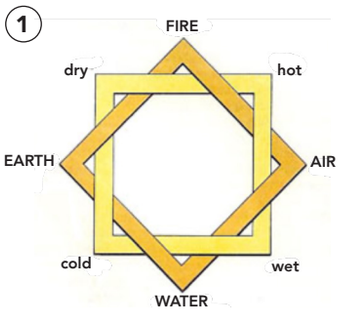
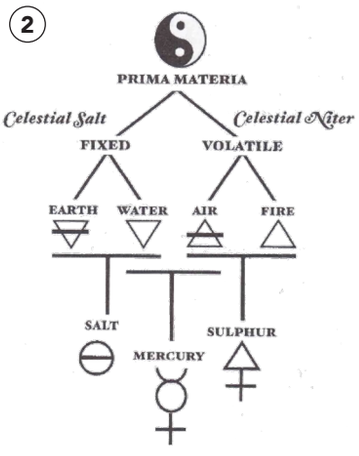
Activity C: How did the periodic table develop? Complete Version cont.

Date	Scientist	Image	Notes
1803	John Dalton	1 	Dalton realised that elements are made of atoms, which combine in fixed whole number ratios to form compounds. He devised symbols for the known elements and ordered them by atomic weights.
1817 – 1829	Johann Döbereiner	2	Dobereiner realised that elements could be grouped by atomic weights and trends in their chemical properties.
1865	John Newlands	3 	Newlands proposed the 'Law of Octaves' to explain his arrangement of the known elements in rows. He found chemical properties repeated every 8th element.
1869	Dimitri Mendeleev	4 	Mendeleev knew that atomic weight measurements were not very accurate. He used chemical properties to order the elements, leaving gaps for new discoveries.

Elements	Atomic weight	Element	Atomic weight	Element	Atomic weight
Li	7	Ca	40	Cl	35.5
Na	23	Sr	88	Br	80
K	39	Ba	137	I	127

1. john dalton chemical elements image - Bing images
2. johann dobereiner triads image - Bing images
3. john newlands octaves chemical elements image - Bing images
4. mendeleev original periodic table image - Bing images

Activity C: How did the periodic table develop? Student Version

Date	Scientist	Image	Notes
Approx 350BCE	Aristotle	1 	
1520	Paracelsus	2 	
1789	Antoine Lavoisier	3 	

3

Noms nouveaux.	Noms anciens correspondans.
Lumière	Lumière.
Calorique	Chaleur. Principe de la chaleur. Fluide igné. Feu. Matière du feu & de la chaleur.
Oxygène	Air déphlogistiqué. Air empiréal. Air vital. Base de l'air vital.
Azote	Gaz phlogistiqué. Mofete. Base de la mofète.
Hydrogène	Gaz inflammable. Base du gaz inflammable.
Soufre	Soufre.
Phofphore	Phofphore.
Carbone	Charbon pur.
Radical muriatique	Inconnu.
Radical fluorique	Inconnu.
Radical boracique	Inconnu.
Antimoine	Antimoine.
Argent	Argent.
Arfenic	Arfenic.
Bifmuth	Bifmuth.
Cobalt	Cobalt.
Cuivre	Cuivre.
Etain	Etain.
Fer	Fer.
Manganèfe	Manganèfe.
Mercure	Mercure.
Molybdène	Molybdène.
Nickel	Nickel.
Or	Or.
Platine	Platine.
Plomb	Plomb.
Tungftène	Tungftène.
Zinc	Zinc.
Chaux	Terre calcaire, chaux.
Magnéfie	Magnéfie, base du fel d'epfom.
Baryte	Barote, terre pefante.
Alumine	Argile, terre de l'alun, base de l'alun.
Silice	Terre filiceufe, terre vitrifiable.

1. aristotle chemical elements image - Bing images
2. paracelsus prima materia image - Bing images
3. lavoisier chemical elements image - Bing images

Activity C: How did the periodic table develop? Student Version cont.

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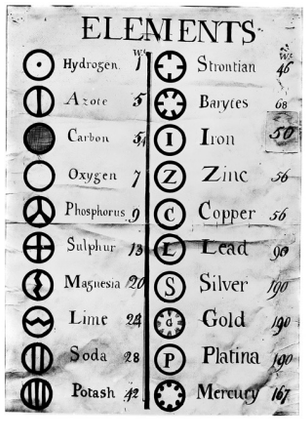
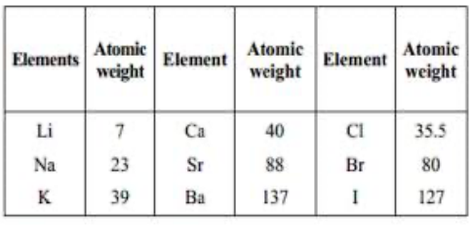
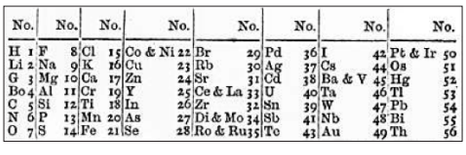
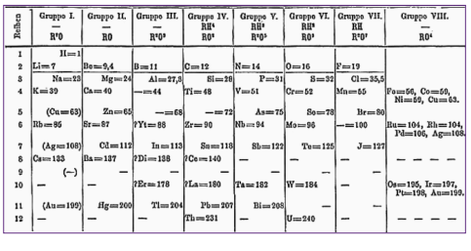
1803	John Dalton	1 	
1817 – 1829	Johann Döbereiner	2 	
1865	John Newlands	3 	
1869	Dimitri Mendeleev	4 	

Elements	Atomic weight	Element	Atomic weight	Element	Atomic weight
Li	7	Ca	40	Cl	35.5
Na	23	Sr	88	Br	80
K	39	Ba	137	I	127

No.	No.	No.	No.	No.	No.	No.	No.
H 1	F 8	Cl 15	Co & Ni 22	Br 29	Pd 36	I 42	Pt & Ir 50
Li 2	Na 9	K 16	Cu 23	Rb 30	Ag 37	Cs 44	Os 51
G 3	Mg 10	Ca 17	Zn 24	Sr 31	Cd 38	Ba & V 45	Hg 52
Bo 4	Al 11	Cr 19	Y 25	Ce & La 33	U 40	Ta 46	Tl 53
C 5	Si 12	Ti 18	In 26	Zr 32	Sn 39	W 47	Pb 54
N 6	P 13	Mn 20	As 27	Di & Mo 34	Sb 41	Nb 48	Bi 55
O 7	S 14	Fe 21	Se 28	Ro & Ru 35	Te 43	Au 49	Th 56

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