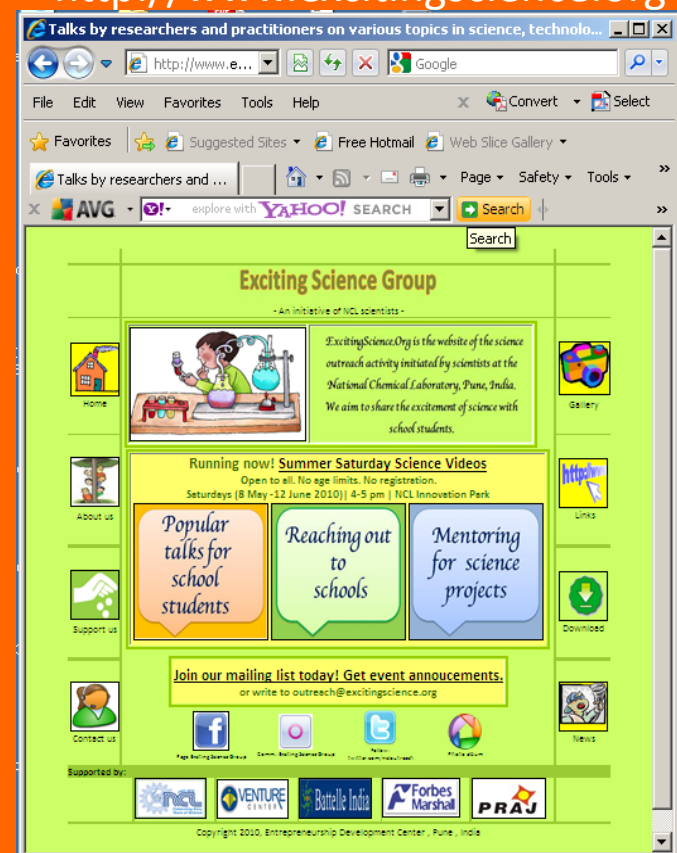


# THE DISCOVERY OF ELEMENTS

Dr. K. Guruswamy  
National Chemical Laboratory (NCL), Pune.

<http://www.excitingscience.org>



SUPPORTED BY:



# What are ELEMENTS?

PURE chemical substances having ONE type of ATOM

Examples: Hydrogen, Carbon, Iron, Gold, Oxygen, Calcium, Zinc, Copper, etc. (Which is the lightest?)

118 elements discovered until now, of which 94 occur naturally on our planet.

Did we always know all 118? Not really...

# PERIODIC TABLE OF THE ELEMENTS

1869

<http://www.ktf-split.hr/periodni/en/>

| GROUP  | 1                                  | 2                                   | 3                                   | 4                                   | 5                                      | 6                                    | 7                                    | 8                                  | 9                                    | 10                                   | 11                                   | 12                                   | 13                                | 14                                     | 15                                 | 16                                   | 17                                 | 18                               |
|--------|------------------------------------|-------------------------------------|-------------------------------------|-------------------------------------|----------------------------------------|--------------------------------------|--------------------------------------|------------------------------------|--------------------------------------|--------------------------------------|--------------------------------------|--------------------------------------|-----------------------------------|----------------------------------------|------------------------------------|--------------------------------------|------------------------------------|----------------------------------|
| PERIOD | 1                                  | 2                                   | 3                                   | 4                                   | 5                                      | 6                                    | 7                                    | 8                                  | 9                                    | 10                                   | 11                                   | 12                                   | 13                                | 14                                     | 15                                 | 16                                   | 17                                 | 18                               |
| 1      | 1 1.0079<br><b>H</b><br>HYDROGEN   |                                     |                                     |                                     |                                        |                                      |                                      |                                    |                                      |                                      |                                      |                                      |                                   |                                        |                                    |                                      |                                    | 2 4.0026<br><b>He</b><br>HELIUM  |
| 2      | 3 6.941<br><b>Li</b><br>LITHIUM    | 4 9.0122<br><b>Be</b><br>BERYLLIUM  |                                     |                                     |                                        |                                      |                                      |                                    |                                      |                                      |                                      |                                      |                                   |                                        |                                    |                                      |                                    |                                  |
| 3      | 11 22.990<br><b>Na</b><br>SODIUM   | 12 24.305<br><b>Mg</b><br>MAGNESIUM |                                     |                                     |                                        |                                      |                                      |                                    |                                      |                                      |                                      |                                      |                                   |                                        |                                    |                                      |                                    |                                  |
| 4      | 19 39.098<br><b>K</b><br>POTASSIUM | 20 40.078<br><b>Ca</b><br>CALCIUM   | 21 44.956<br><b>Sc</b><br>SCANDIUM  | 22 47.867<br><b>Ti</b><br>TITANIUM  | 23 50.942<br><b>V</b><br>VANADIUM      | 24 51.996<br><b>Cr</b><br>CHROMIUM   | 25 52.004<br><b>Mn</b><br>MANGANESE  | 26 55.845<br><b>Fe</b><br>IRON     | 27 58.933<br><b>Co</b><br>COBALT     | 28 58.933<br><b>Ni</b><br>NICKEL     | 29 63.546<br><b>Cu</b><br>COPPER     | 30 65.38<br><b>Zn</b><br>ZINC        | 31 69.723<br><b>Ga</b><br>GALLIUM | 32 72.64<br><b>Ge</b><br>GERMANIUM     | 33 74.922<br><b>As</b><br>ARSENIC  | 34 78.96<br><b>Se</b><br>SELENIUM    | 35 79.904<br><b>Br</b><br>BROMINE  | 36 83.80<br><b>Kr</b><br>KRYPTON |
| 5      | 37 85.468<br><b>Rb</b><br>RUBIDIUM | 38 87.62<br><b>Sr</b><br>STRONTIUM  | 39 88.906<br><b>K</b><br>YTTRIUM    | 40 90.907<br><b>Zr</b><br>ZIRCONIUM | 41 91.224<br><b>Nb</b><br>NIOBIUM      | 42 92.906<br><b>Mo</b><br>MOLYBDENUM | 43 95.94<br><b>Tc</b><br>TECHNETIUM  | 44 101.07<br><b>Ru</b><br>RHODIUM  | 45 102.91<br><b>Rh</b><br>RHODIUM    | 46 106.42<br><b>Pd</b><br>PALLADIUM  | 47 107.87<br><b>Ag</b><br>SILVER     | 48 112.41<br><b>Cd</b><br>CADMIUM    | 49 114.82<br><b>In</b><br>INDIUM  | 50 118.71<br><b>Sn</b><br>TIN          | 51 121.76<br><b>Sb</b><br>ANTIMONY | 52 127.60<br><b>Te</b><br>TELLURIUM  | 53 126.90<br><b>I</b><br>IODINE    | 54 131.29<br><b>Xe</b><br>XENON  |
| 6      | 55 132.91<br><b>Cs</b><br>CAESIUM  | 56 137.33<br><b>Ba</b><br>BARIUM    | 57 138.91<br><b>La</b><br>LANTHANUM | 58 140.12<br><b>Ce</b><br>CERIUM    | 59 140.91<br><b>Pr</b><br>PRASEODYMIUM | 60 144.24<br><b>Nd</b><br>NEODYMIUM  | 61 144.24<br><b>Pm</b><br>PROMETHIUM | 62 150.36<br><b>Sm</b><br>SAMARIUM | 63 151.96<br><b>Eu</b><br>EUROPIUM   | 64 157.25<br><b>Gd</b><br>GADOLINIUM | 65 158.93<br><b>Tb</b><br>TERBIUM    | 66 162.50<br><b>Dy</b><br>DYSPROSIUM | 67 164.93<br><b>Ho</b><br>HOLMIUM | 68 167.26<br><b>Er</b><br>ERBIUM       | 69 168.93<br><b>Tm</b><br>THULIUM  | 70 173.04<br><b>Yb</b><br>YTTTERBIUM | 71 174.97<br><b>Lu</b><br>LUTETIUM |                                  |
| 7      | 87 (223)<br><b>Fr</b><br>FRANCIUM  | 88 (226)<br><b>Ra</b><br>RADIUM     | 89-103<br><b>Ac-Lr</b><br>ACTINIDE  | 104 (261)<br><b>Rf</b><br>RUTHENIUM | 105 (262)<br><b>Db</b><br>DUBNIUM      | 106 (263)<br><b>Sg</b><br>SEABORGIUM | 107 (264)<br><b>Bh</b><br>BOHRHIUM   | 108 (277)<br><b>Hs</b><br>HASSIUM  | 109 (268)<br><b>Mt</b><br>MEITNERIUM | 110 (281)<br><b>Uun</b><br>UNUNNIUM  | 111 (272)<br><b>Uuu</b><br>UNUNUNIUM | 112 (285)<br><b>Uub</b><br>UNBIBIUM  | 113<br><b>Uut</b><br>UNUNTRIUM    | 114 (289)<br><b>Uuq</b><br>UNUNQUADIUM |                                    |                                      |                                    |                                  |

## LANTHANIDE

|                                     |                                  |                                        |                                     |                                     |                                    |                                    |                                      |                                   |                                      |                                   |                                  |                                   |                                      |                                    |
|-------------------------------------|----------------------------------|----------------------------------------|-------------------------------------|-------------------------------------|------------------------------------|------------------------------------|--------------------------------------|-----------------------------------|--------------------------------------|-----------------------------------|----------------------------------|-----------------------------------|--------------------------------------|------------------------------------|
| 57 138.91<br><b>La</b><br>LANTHANUM | 58 140.12<br><b>Ce</b><br>CERIUM | 59 140.91<br><b>Pr</b><br>PRASEODYMIUM | 60 144.24<br><b>Nd</b><br>NEODYMIUM | 61 (145)<br><b>Pm</b><br>PROMETHIUM | 62 150.36<br><b>Sm</b><br>SAMARIUM | 63 151.96<br><b>Eu</b><br>EUROPIUM | 64 157.25<br><b>Gd</b><br>GADOLINIUM | 65 158.93<br><b>Tb</b><br>TERBIUM | 66 162.50<br><b>Dy</b><br>DYSPROSIUM | 67 164.93<br><b>Ho</b><br>HOLMIUM | 68 167.26<br><b>Er</b><br>ERBIUM | 69 168.93<br><b>Tm</b><br>THULIUM | 70 173.04<br><b>Yb</b><br>YTTTERBIUM | 71 174.97<br><b>Lu</b><br>LUTETIUM |
|-------------------------------------|----------------------------------|----------------------------------------|-------------------------------------|-------------------------------------|------------------------------------|------------------------------------|--------------------------------------|-----------------------------------|--------------------------------------|-----------------------------------|----------------------------------|-----------------------------------|--------------------------------------|------------------------------------|

## ACTINIDE

|                                   |                                   |                                        |                                  |                                    |                                    |                                    |                                 |                                    |                                      |                                      |                                   |                                       |                                    |                                      |
|-----------------------------------|-----------------------------------|----------------------------------------|----------------------------------|------------------------------------|------------------------------------|------------------------------------|---------------------------------|------------------------------------|--------------------------------------|--------------------------------------|-----------------------------------|---------------------------------------|------------------------------------|--------------------------------------|
| 89 (227)<br><b>Ac</b><br>ACTINIUM | 90 232.04<br><b>Th</b><br>THORIUM | 91 231.04<br><b>Pa</b><br>PROTACTINIUM | 92 238.03<br><b>U</b><br>URANIUM | 93 (237)<br><b>Np</b><br>NEPTUNIUM | 94 (244)<br><b>Pu</b><br>PLUTONIUM | 95 (243)<br><b>Am</b><br>AMERICIUM | 96 (247)<br><b>Cm</b><br>CURIUM | 97 (247)<br><b>Bk</b><br>BERKELIUM | 98 (251)<br><b>Cf</b><br>CALIFORNIUM | 99 (252)<br><b>Es</b><br>EINSTEINIUM | 100 (257)<br><b>Fm</b><br>FERMIUM | 101 (258)<br><b>Md</b><br>MENDELEVIUM | 102 (259)<br><b>No</b><br>NOBELIUM | 103 (262)<br><b>Lr</b><br>LAWRENCIUM |
|-----------------------------------|-----------------------------------|----------------------------------------|----------------------------------|------------------------------------|------------------------------------|------------------------------------|---------------------------------|------------------------------------|--------------------------------------|--------------------------------------|-----------------------------------|---------------------------------------|------------------------------------|--------------------------------------|

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(1) Pure Appl. Chem., 73, No. 4, 667-683 (2001)  
Relative atomic mass is shown with five significant figures. For elements having no stable nuclides, the value enclosed in brackets indicates the mass number of the longest-lived isotope of the element.

Over three such elements (Th, Pa, and U) have a characteristic terrestrial isotopic composition, and for these an atomic weight is listed.

Editor: Aditya Vardhan (adivar@netlinx.com)

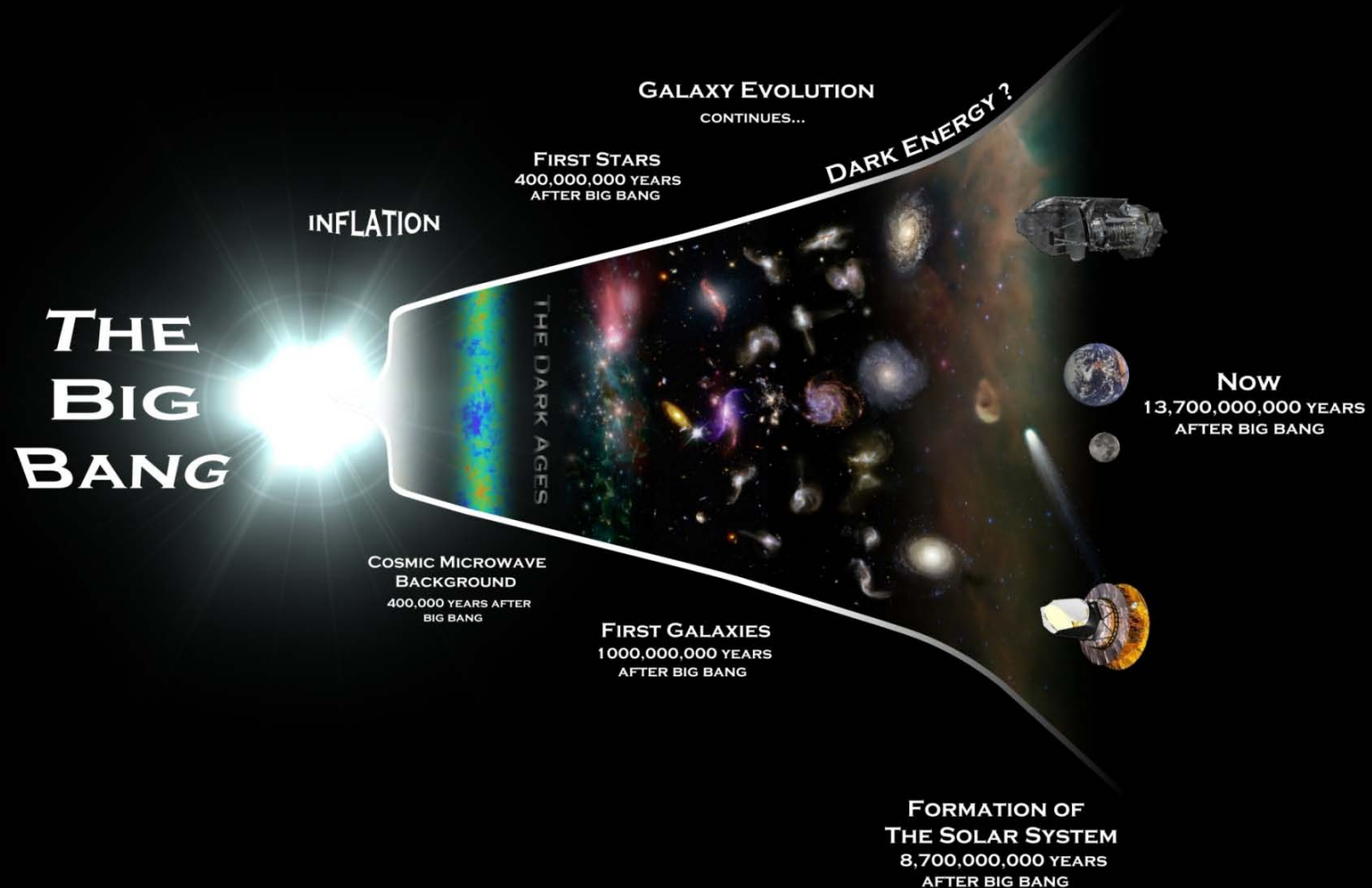
<http://www.wikipedia.org>

DMITRI MENDELEEV (1834 – 1907)

**But first,  
some even older history...**

# Let us start at the very beginning: All elements are born in stars

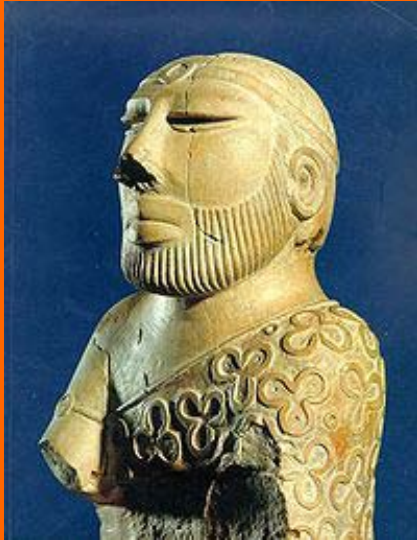
## Nucleosynthesis in stars



**Fast forward to a few  
thousand years ago:  
The ANCIENT times**

# “Elements” in the Ancient World India/Greece/..

PRITHVI



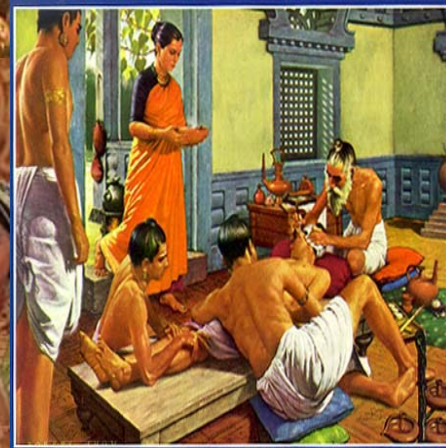
AKASH



VAYU



JAL



AGNI



# The Ancients Knew Some Elements

Gold, Silver, Copper, **Carbon**, Sulphur,  
Mercury, Tin, Lead, Iron,

Known to Greeks, Romans,  
Egyptians/Middle East, Chinese, Indians



# CARBON – LIFE IS CARBON-BASED

## THE CHEMISTRY OF CARBON-CARBON BONDS

Chemists want to control making/breaking C-C bonds

Many **NOBEL PRIZES** for learning to make/break C-C bonds

Nobel prize – MOST prestigious science prize

POLYMERS – from C-C bonds

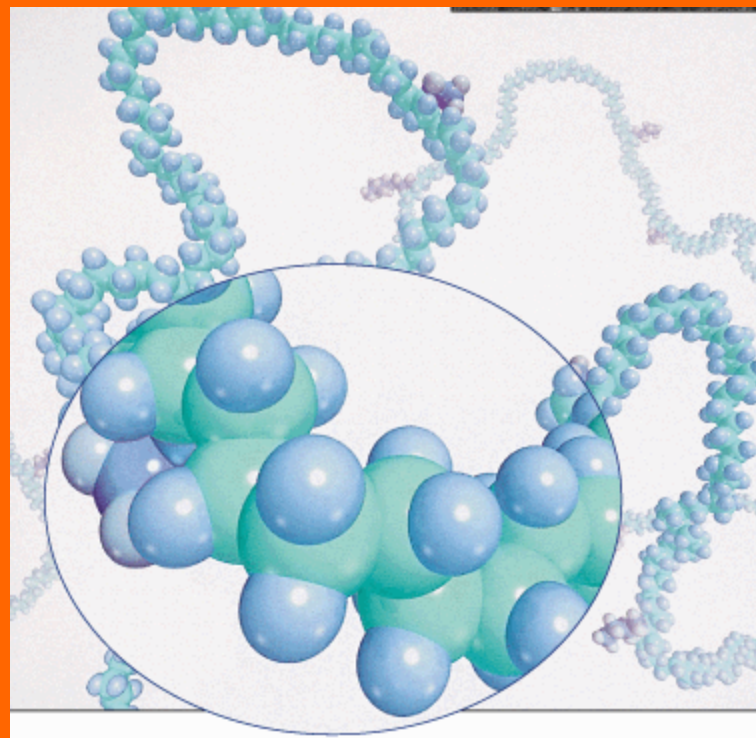
PROTEINS, DNA are polymers

## SYNTHETIC POLYMERS

Polythene

Nylon

Rubber



# C-C BOND FORMATION IN NYLON

DEMONSTRATION:  
Synthesis of NYLON

# POLYACRYLIC ACID: Gelation

DEMONSTRATION:  
Gelation

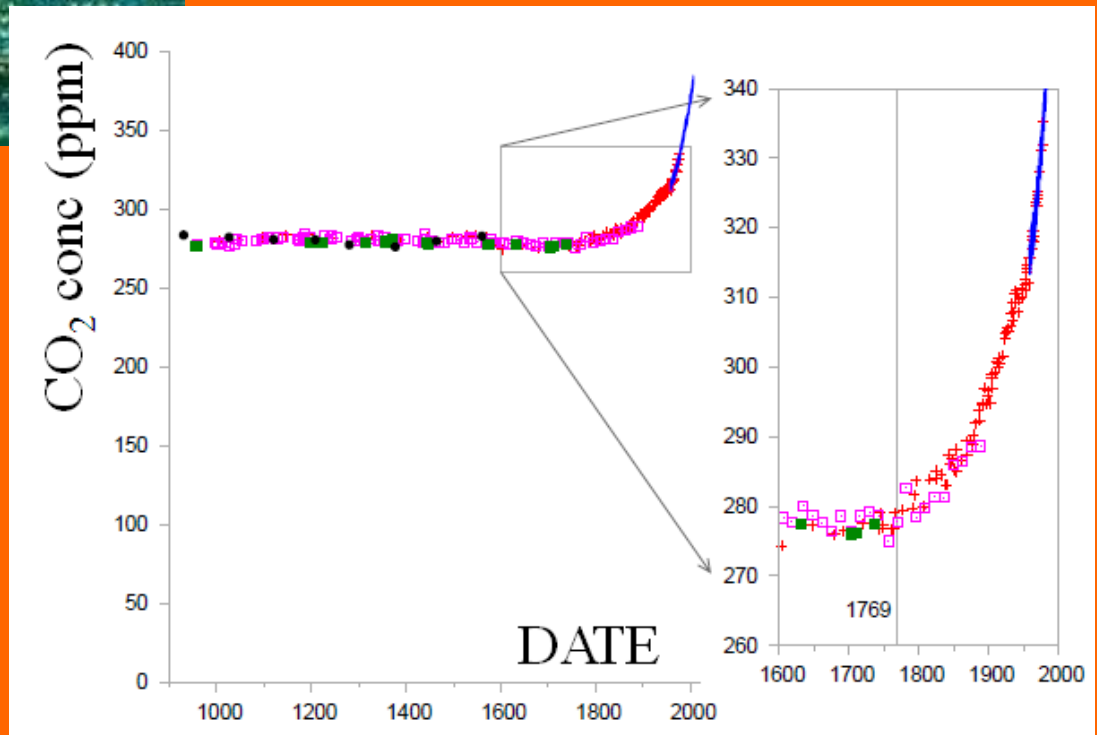
# CARBON COMPOUNDS/CO<sub>2</sub>



Oil: The starting point for polymers

Why I chose to get into science...

CO<sub>2</sub>: Problems due to our extreme reliance on carbon based fossil fuels



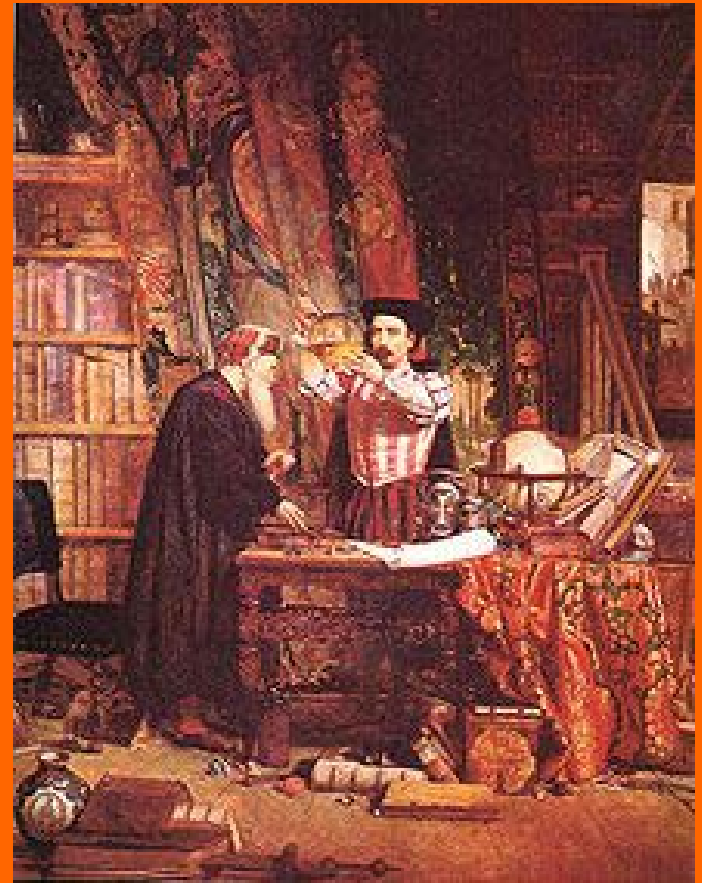
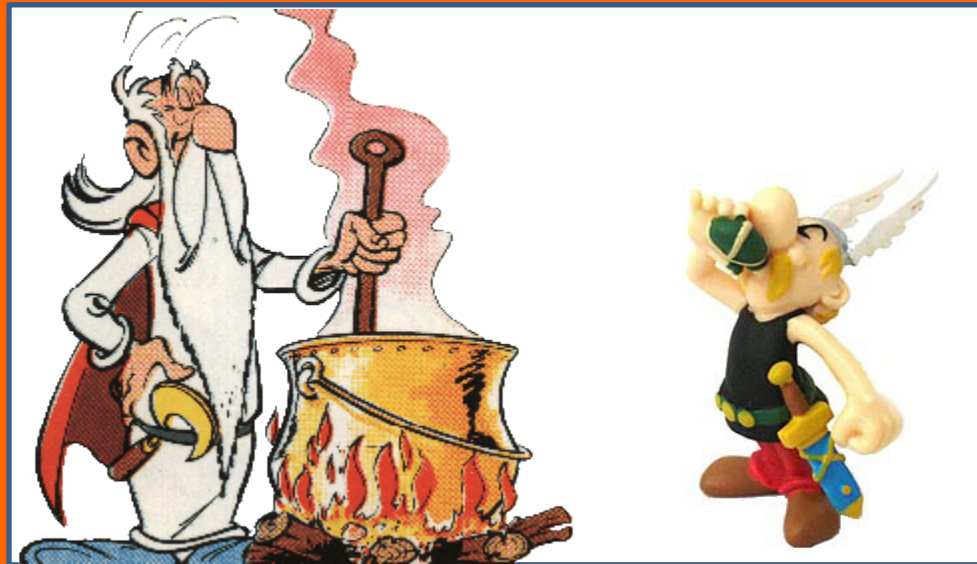
**Fast forward from  
ancient times to a few  
hundred years ago:  
The MEDIEVAL times**

# Fast Forward to the MEDIEVAL AGE in Europe

SEARCH FOR:  
PHILOSOPHER'S STONE

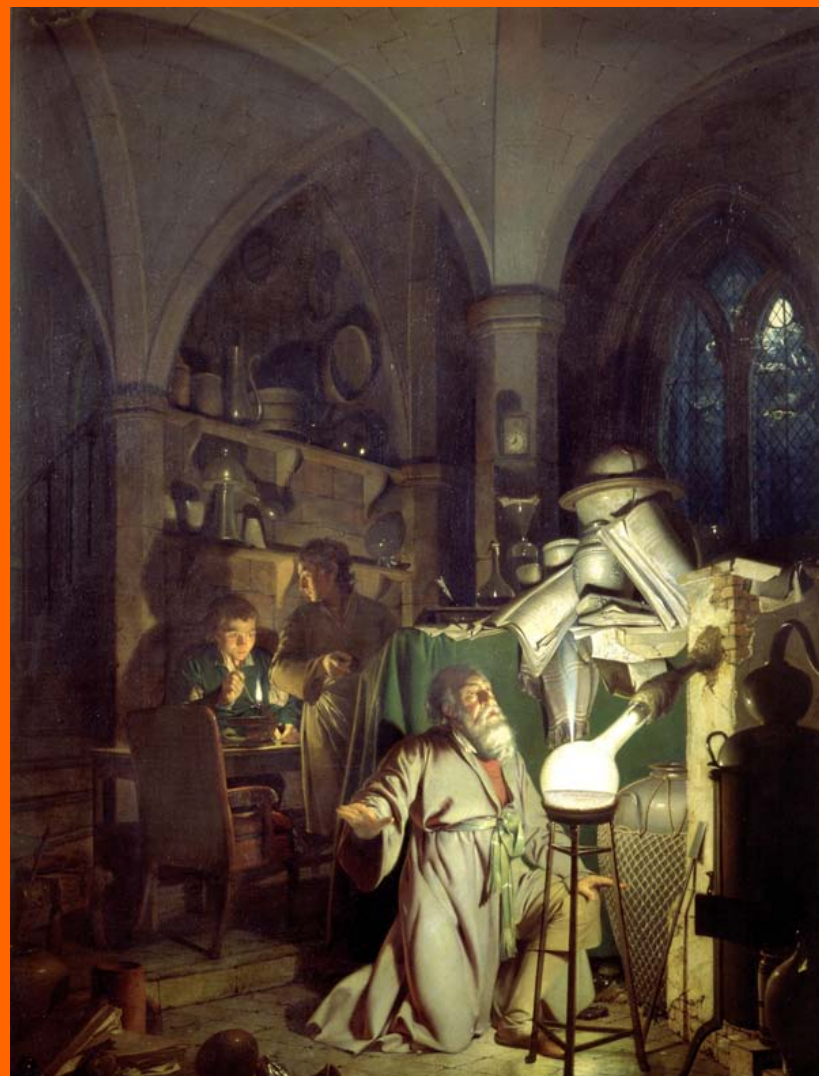
Convert metals into GOLD

ELIXIR of LIFE



# PHOSPHOROUS (P)

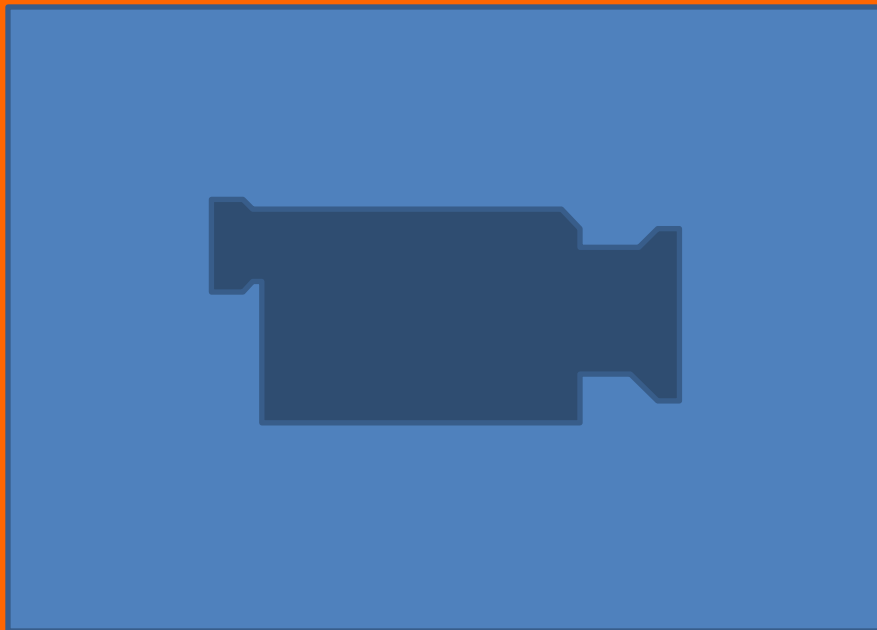
Henning Brand, Hamburg, Germany  
1669



White phosphorous is DANGEROUS  
Volatile, Toxic (Phossy Jaw)  
Highly inflammable



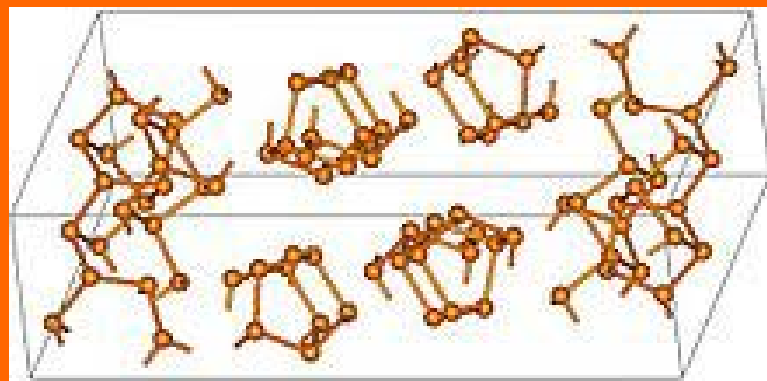
# White P<sub>4</sub> – Video



# Red P<sub>4</sub> – Safety Matches



Red phosphorous + powdered glass

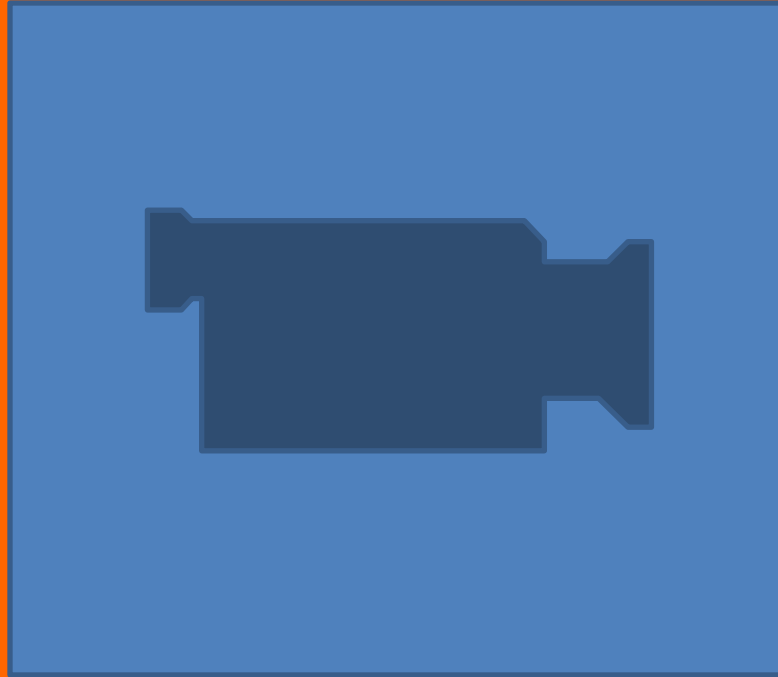


Potassium chlorate + binder

# RED PHOSPHOROUS: The Match Experiment

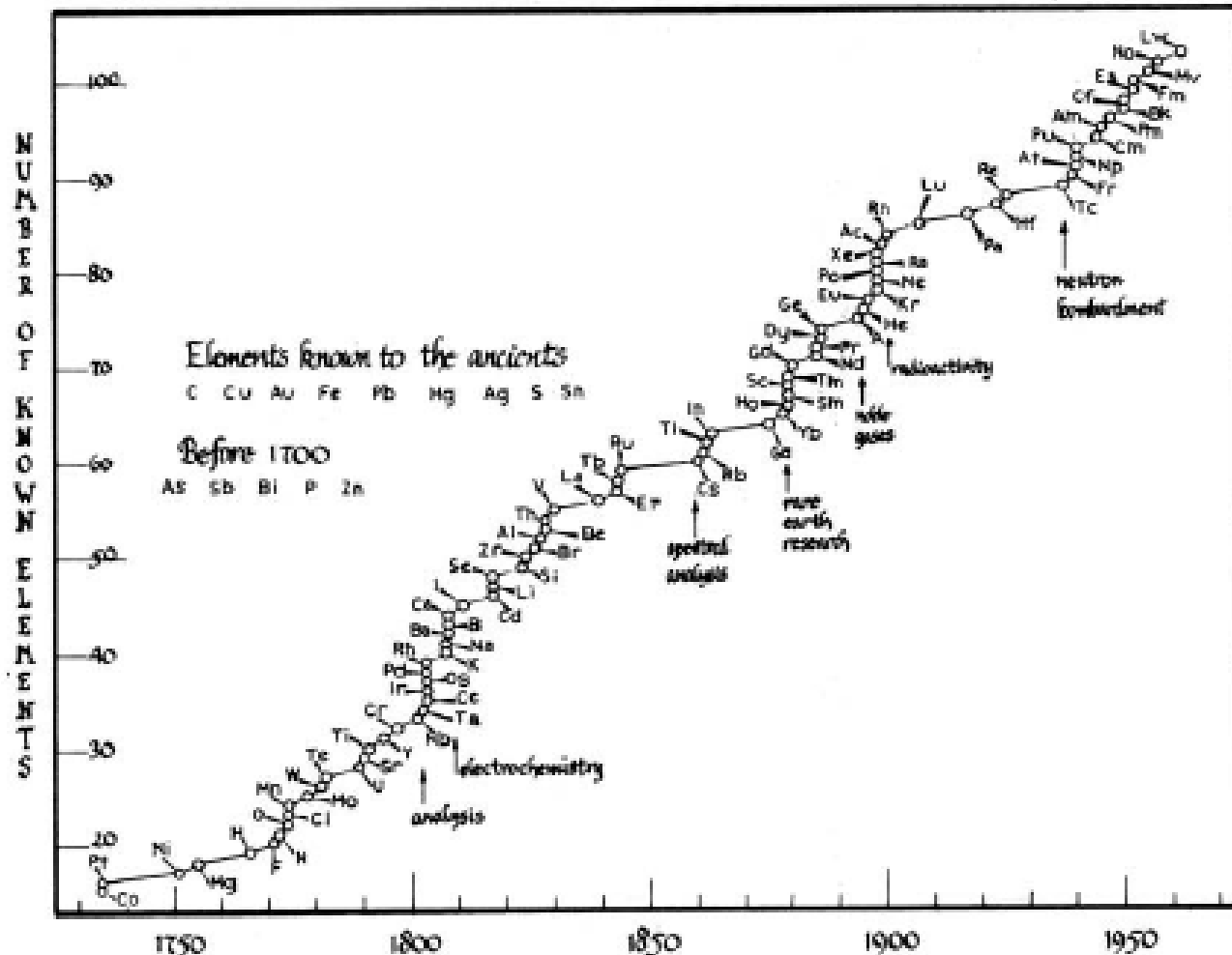
Demonstration

# Discovery of ELEMENTS



# Discovery of ELEMENTS

Chronology of the Discovery of the Elements



# THE ERA OF ELECTROCHEMISTRY

In 1800, Volta invented  
the BATTERY

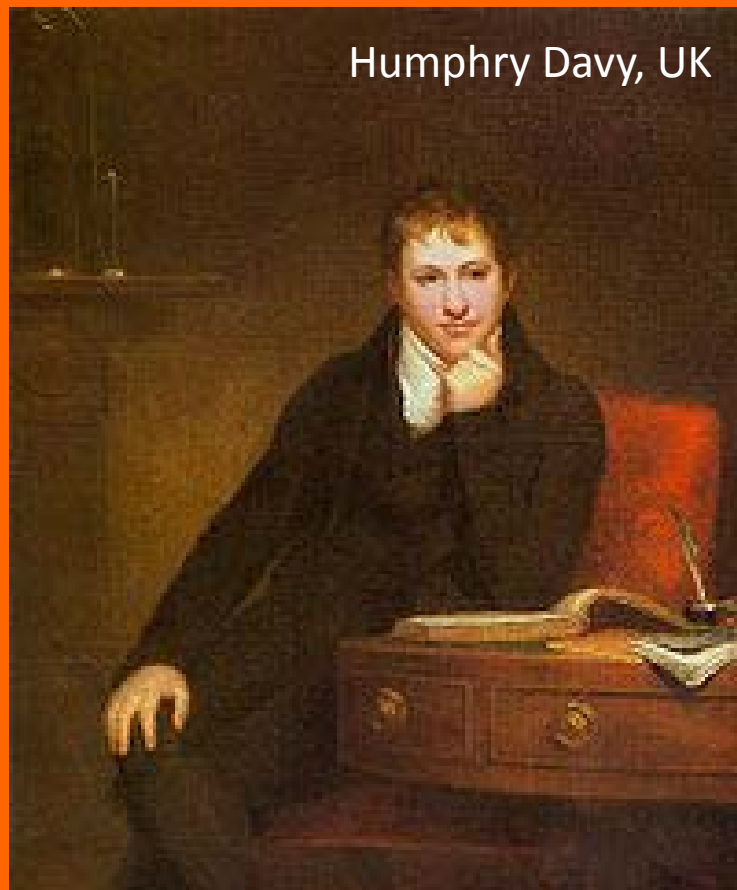
1.5 VOLT battery



Humphrey Davy discovered 5 elements  
(1807 – 1808): Strontium, Magnesium,  
Boron, Calcium, Barium

Davy's father was a woor carver. Davy  
came from a modest background, but  
attended school and taught himself  
philosophy, science and poetry.

Humphry Davy, UK



Became the most famous chemist in UK

# Humphry Davy: Demonstrations



# DEMONSTRATION



Electrolysis

# Magnesium

FIREWORKS



FLARES



# DEMONSTRATION

Mg burning

# THE ERA OF ELECTROCHEMISTRY



Henri Moissan, Switzerland



USED ELECTROLYSIS OF HF (ACID) TO GET FLUORINE

PRIZE OF 10000 SWISS FRANCS WHEN HE COULD  
REPRODUCE THIS WORK (POTASSIUM FLUORIDE  
IMPURITY WAS REQUIRED)

1906 NOBEL PRIZE IN CHEMISTRY  
(MENDELEEV WAS NOMINATED BUT DIDN'T GET IT)

# SPECTROSCOPY



Kirchhoff

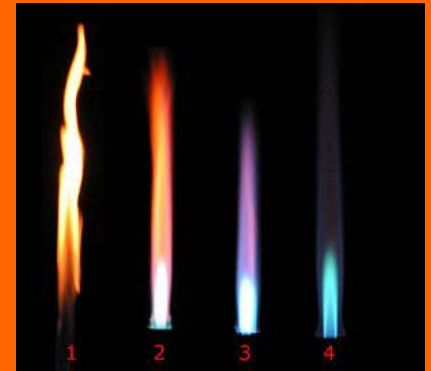
Bunsen

Kirchhoff:  
Physicist, Laws for  
electrical circuits

Bunsen:  
Chemist

Shine light through  
intense, hot,  
nonluminous flame.  
Analyze the SPECTRUM

Identified Cesium and  
Rubidium

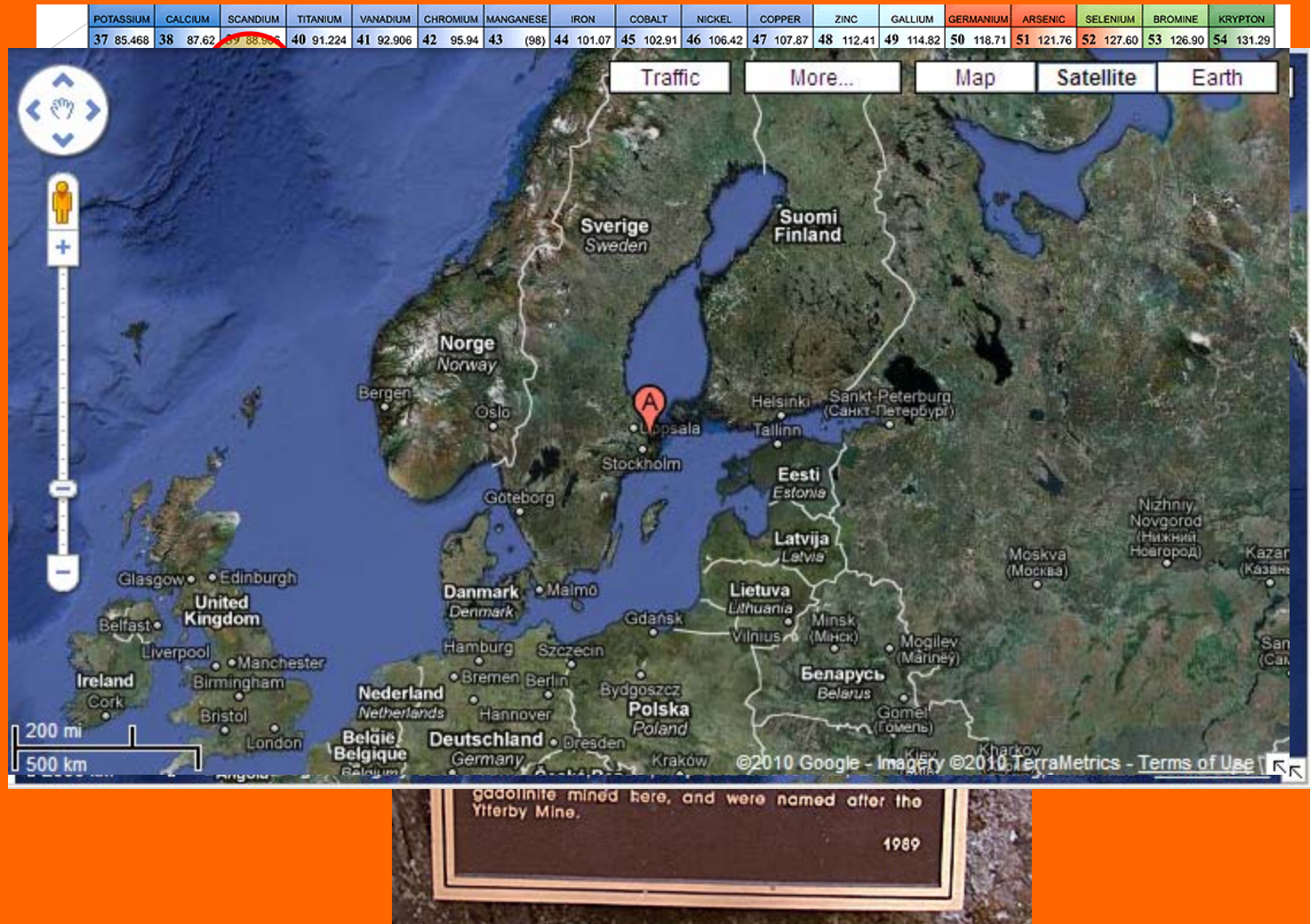


Bunsen burner

# SPECTROSCOPY – FLAME TEST

DEMONSTRATION:  
Flame Test

# SPECTROSCOPY – RARE EARTHS



# RARE EARTH

Are not really RARE

Exist in high concentrations in the earth's crust

Difficult to mine

## VERY IMPORTANT APPLICATIONS

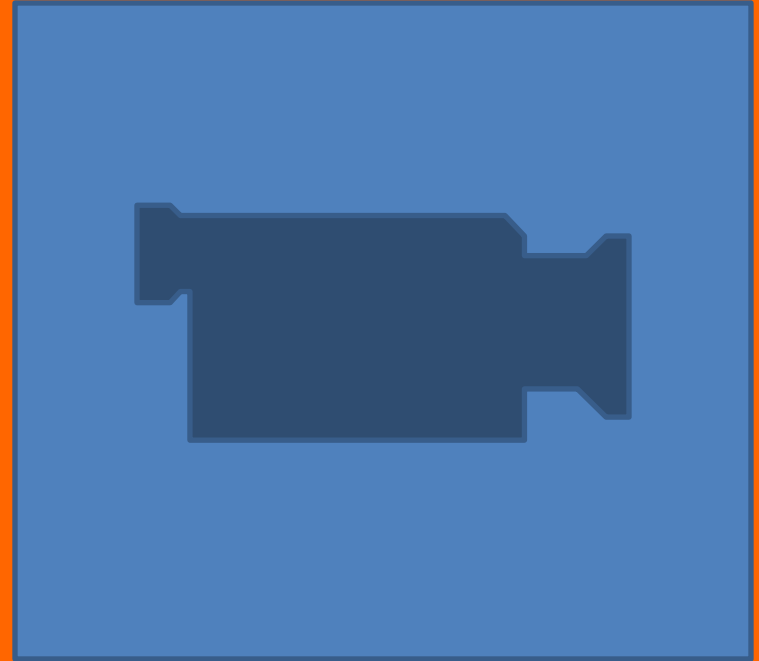
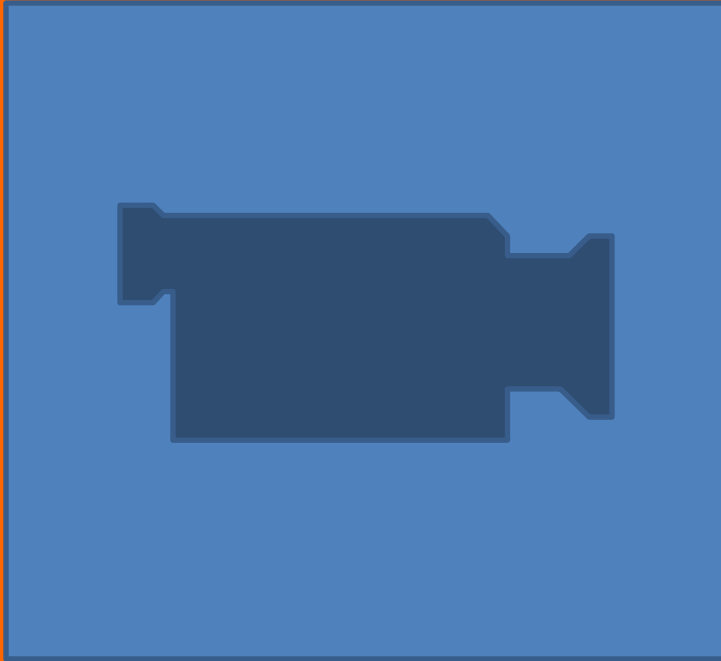
Neodymium; Samarium: POWERFUL MAGNETS (ELECTRONICS, COMPUTERS, MOTORS/GENERATORS), LASERS

Yttrium: MICROWAVE RESONATORS

PHOSPHORS for TV SCREENS, SUPERCONDUCTORS

Today, CHINA produces 95% of all RARE EARTH MINERALS

# RARE EARTH MAGNETS

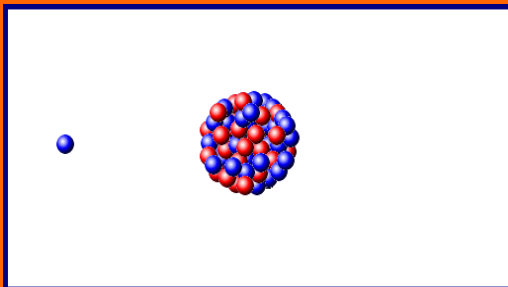
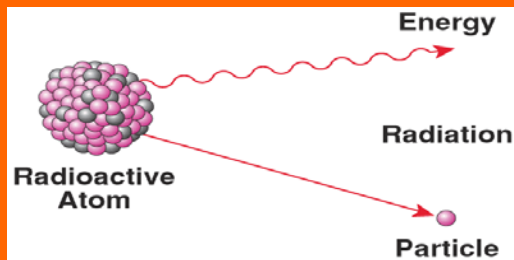


# Demonstration

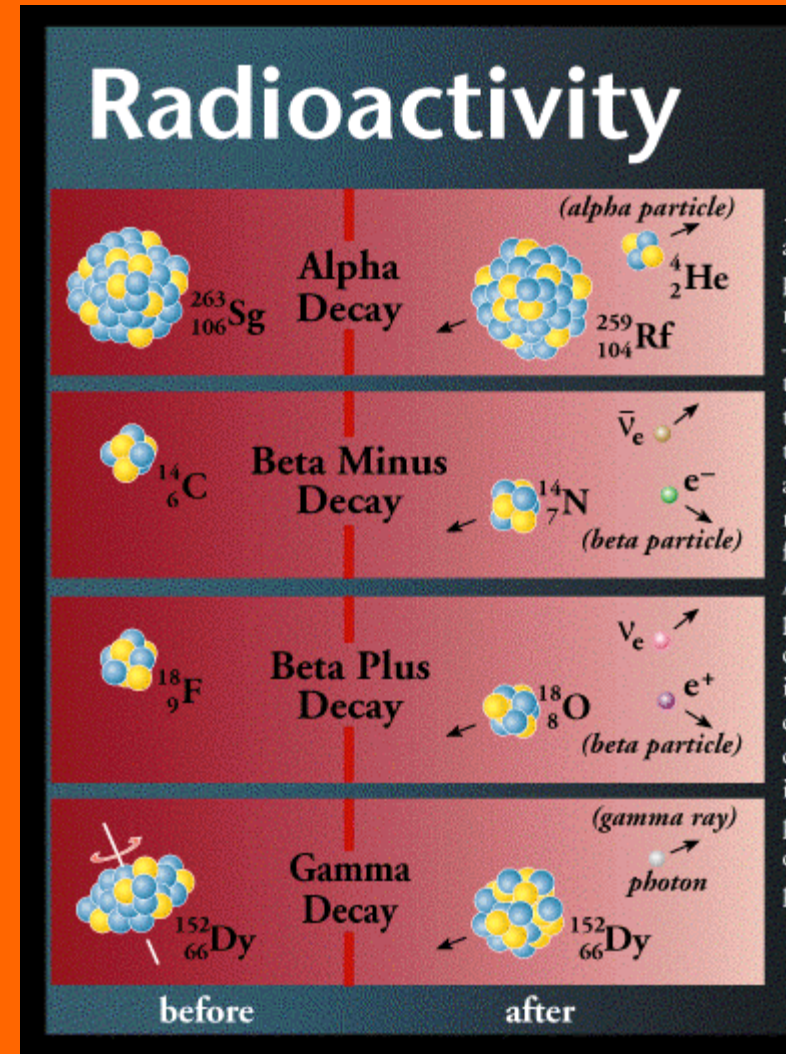
Magnetic Braking

# NATURAL RADIOACTIVITY

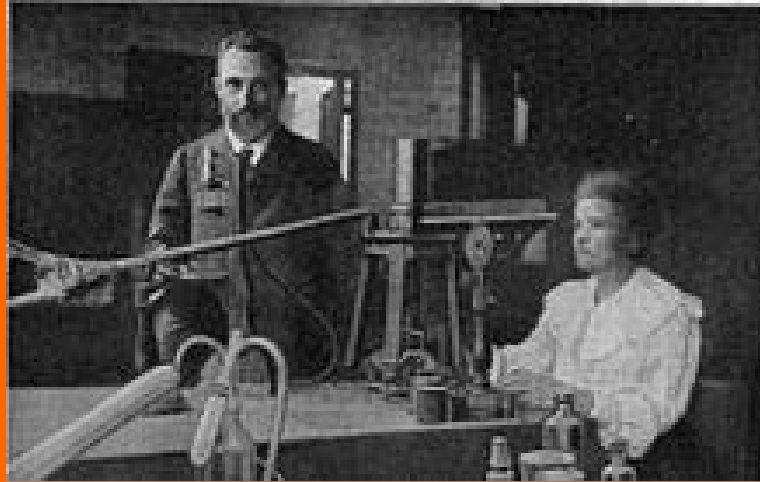
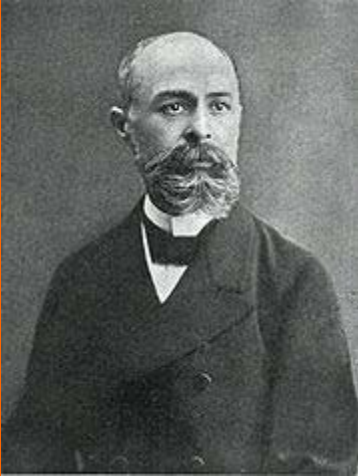
Unstable nuclei emit light or particles (like alpha particles, electrons) and rearrange to form a less excited state



Fission/ Fissile break up is the basis of nuclear power/weapons



# MARIE CURIE



Nobel Prize in Physics – 1903  
Becquerel, Pierre and Marie  
Curie

Research on “radiation  
phenomena”

Nobel Prize in Chemistry – 1911 (IYC:2011 in honour of this)  
Discovery of radium and polonium

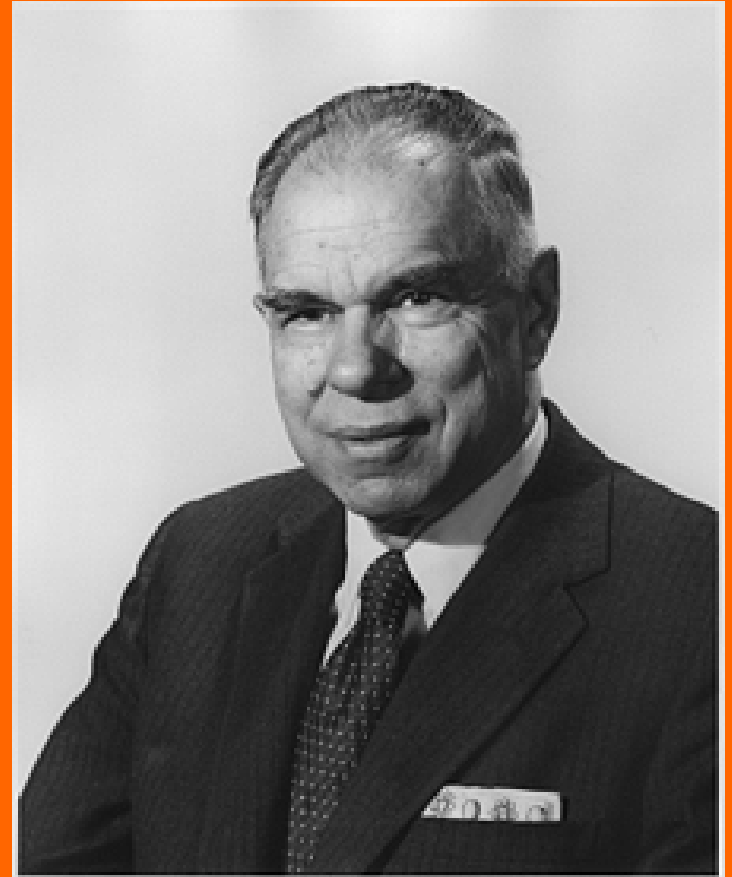
Could not find a position at Krakow University in Poland  
Did not get elected to the French Academy of Sciences

Marie Curie grew up poor, but was well educated. Her father  
was a teacher of mathematics and physics in Poland.



# ARTIFICIALLY-MADE ELEMENTS

Discovered /MADE 10 new elements  
1951 Nobel Prize in Chemistry



Glenn T. Seaborg, USA

# THE LATEST ELEMENT: 117



# RESOURCES

[http://en.wikipedia.org/wiki/Timeline\\_of\\_chemical\\_elements\\_discoveries](http://en.wikipedia.org/wiki/Timeline_of_chemical_elements_discoveries)  
<http://chemistry.about.com/od/elementfacts/a/timeline-element-discovery.htm>  
[http://education.jlab.org/ga/discover\\_ele.html](http://education.jlab.org/ga/discover_ele.html)  
<http://www.rsc.org/education/teachers/learnnet/periodictable/pre16/discover.doc>  
<http://elements.vanderkrogt.net/>  
<http://www.webelements.com/>  
[http://en.wikipedia.org/wiki/Periodic\\_table](http://en.wikipedia.org/wiki/Periodic_table)  
<http://www.rsc.org/chemsoc/visualelements/pages/pertable fla.htm>  
<http://www.chemheritage.org/>  
<http://www.aip.org/history/curie/periodic.htm>  
VIDEOS from: <http://www.youtube.com> and <http://arvindguptatoys.com>  
117 video from the Livermore Lab, taken from [www.youtube.com](http://www.youtube.com)

# ACKNOWLEDGEMENTS

United Phosphorous (Mr. K. Desai) for the white phosphorous  
Electroplating trials: Dr. K. Sreekumar and Dr. K. Krishnamoorthy (NCL)  
Arvind Gupta (for inspiration, and for the rare earth magnets)  
Dr. Sayam Sengupta, Yogeshree Phadke and Bhakti Dhamdhare for discussions