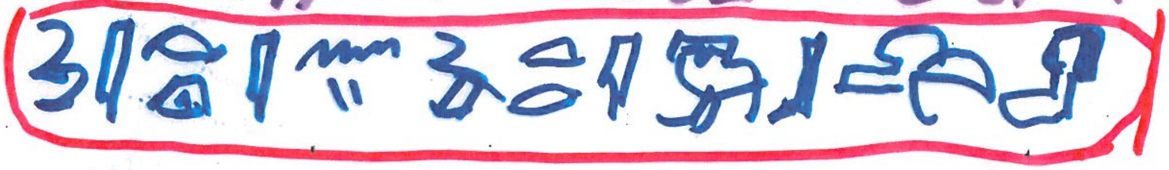
The baryonic Universe — from the Greeks to Grails

Virginia Trimble - UCI & LCOGT



POT-SHOTS NO 1407

WHY AREN'T YOU
MORE GRATEFUL
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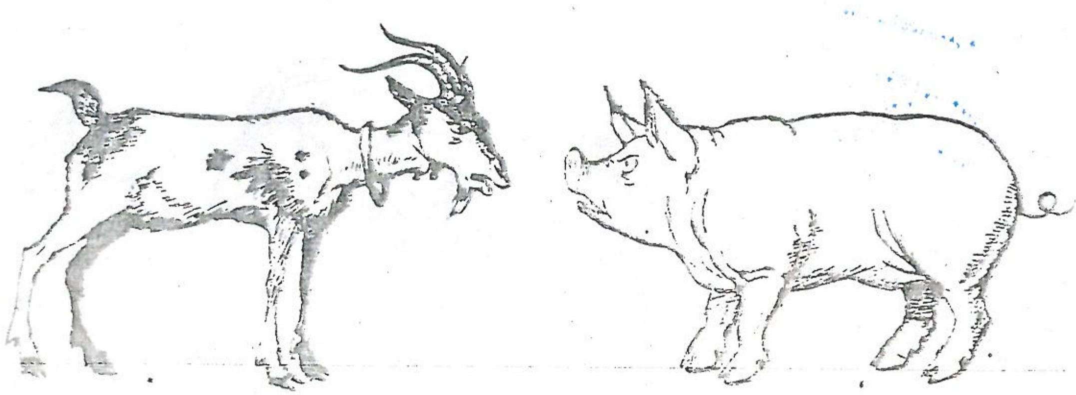
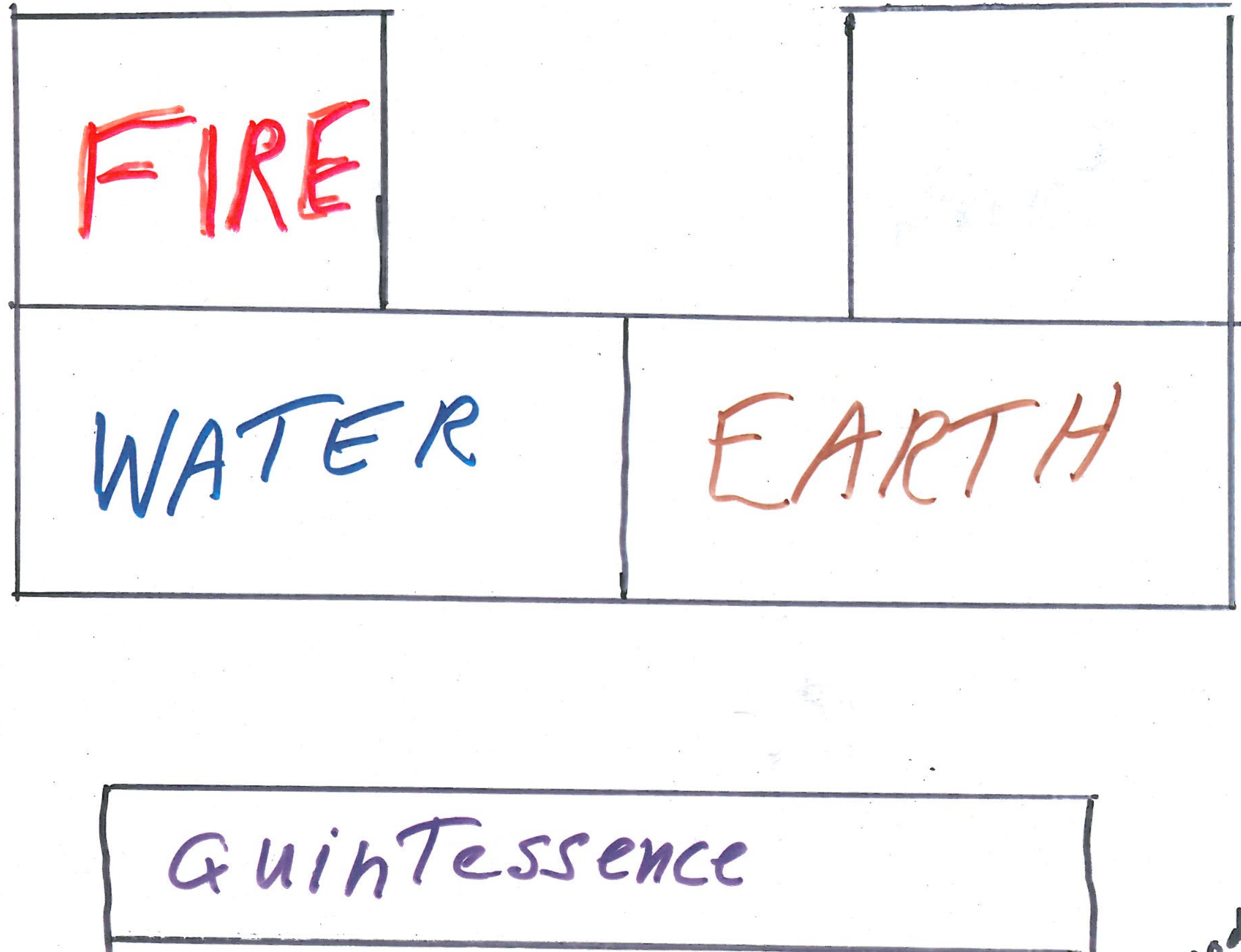
HOW WRONG YOU'VE BEEN?



Ashleigh Brilliant



Ancient Greek Periodic Table

Epicurus, 342 BCE - 270 BCE thoughts preserved in fragments, except
Lucretius, 94 BCE - 51 BCE, De Rerum Natura, lost c. 400 CE to 1420 CE (*)

Wrote that there is nothing but atoms & void.
Atoms solid, tiny, indestructable, no new ones being created. Different sizes & shapes, come together to make things, which eventually decay, fall apart, etc. But universe of things made from atoms moving in the void goes on forever

We are made of the same stuff that everything else is made of and also decay, fall apart
G.d(s) probably exist but have zero interest or interaction with us.

See Stephen Greenblatt, The Swerve, 2011 also very interesting on Bruno

(*) a surviving manuscript found by Poggio, 1417 in S. German abbey, Fulda

DIGGING OUT OF PHLOGISTON & ALL

Prout's hypothesis (more shortly, everything H
Dalton's hypothesis (everything is atoms)

Loschmidt's number (or Avogadro, but L first
& had in hand all the information needed to
get a number, e.g.

rms speed; know R & mass of mole, measure heat capacity & thermal conductivity, get mfp in units of size of molecule. Compare gas & condensed phases to get ratio of mfp to molecule size, thus number of molecules in mole of condensed phase
(from D.V. Schroeder; Wiki pretty good)

c. 1850

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1660–1734

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ANTOINE LAURENT LAVOISIER
1743–1794

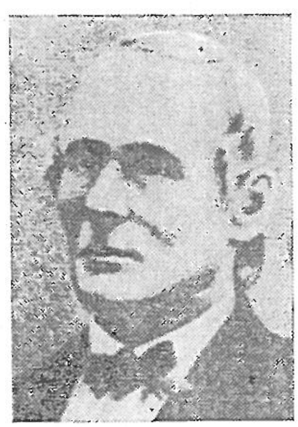
(*Facing*

Robert Bunsen (1811-99) & Gustav Kirchoff (1824-87), 1859 ff, sun (etc) contains same elements as earth

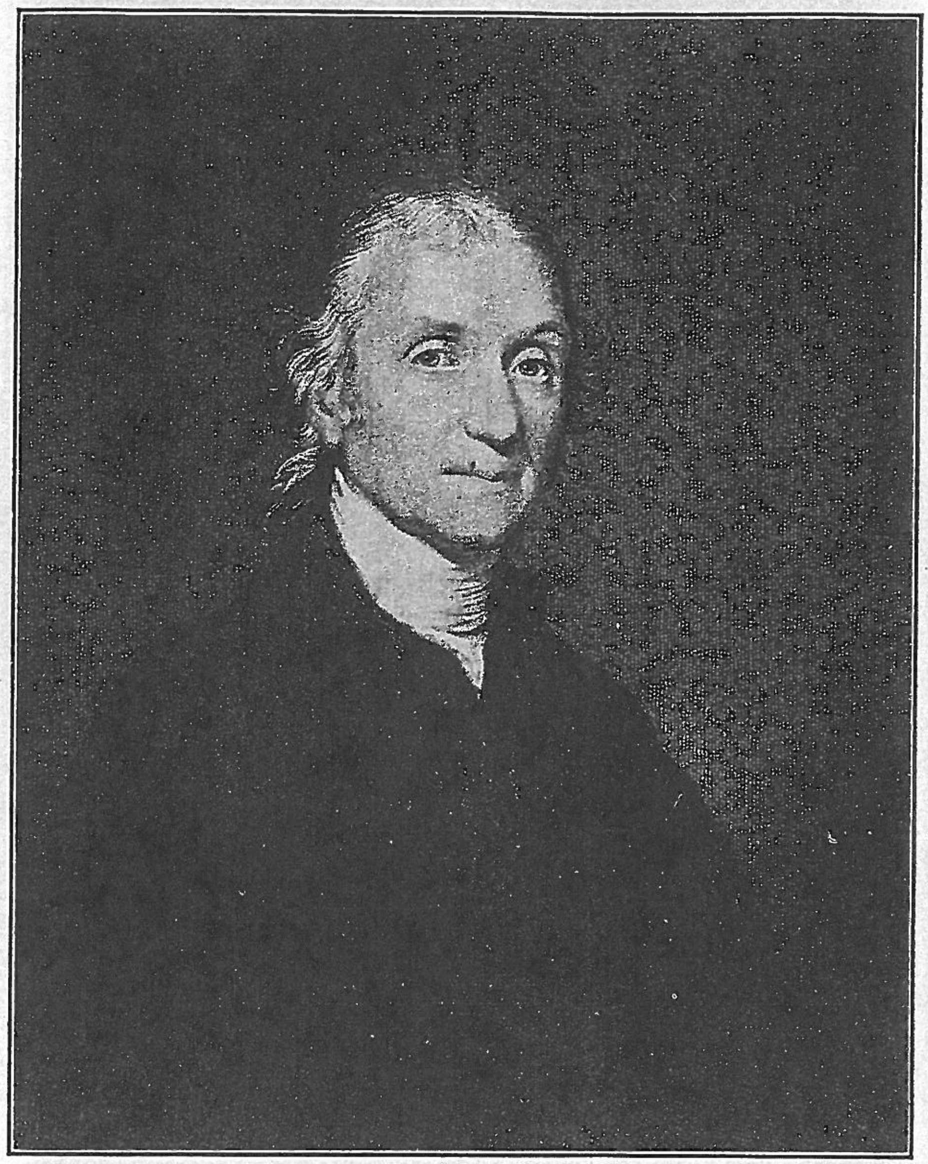
AJ Angstrom, sun has hydrogen; 50 elements by 1890, favoring left side of periodic table (which is electron properties, not nuclear)

K giants mostly H & He, CH Payne (Gaposchkin 1925), Russell, McCrea etc later

КИРХГОФ Густав Роберт
(12.III 1824—17.X 1887)



АНГСТРЕМ (Онгстрём)
Андерс Йонас
(13.VIII 1814—21.VI 1874)



Joseph Priestley
1733–1804

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1660–1734

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Des Substances simples.

Tableau des Substances simples.

	Noms nouveaux.	Noms anciens correſpondans.
Subſtances ſimples qui appartiennent aux trois règnes, & qu'on peut regarder comme les élémens des corps.	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.
		Moſète.
		Baſe de la moſète.
	Hydrogène	Gaz inflammable.
		Baſe du gaz inflammable.
Subſtances ſimples non métalliques oxidables & acidifiables.	Soufre	Soufre.
	Phoſphore	Phoſphore.
	Carbone	Charbon pur.
	Radical muriatique	Inconnu.
	Radical fluorique	Inconnu.
	Radical boracique	Inconnu.
Subſtances ſimples métalliques oxidables & acidifiables.	Antimoine	Antimoine.
	Argent	Argent.
	Arſenic	Arſenic.
	Biſmuth	Biſmuth.
	Cobalt	Cobalt.
	Cuivre	Cuivre.
	Etain	Etain.
	Fer	Fer.
	Manganèſe	Manganèſe.
	Mercure	Mercure.
	Molybdène	Molybdène.
	Nickel	Nickel.
	Or	Or.
	Platine	Platine.
	Plomb	Plomb.
	Tungſtène	Tungſtène.
	Zinc	Zinc.
Subſtances ſimples ſalifiables terreuſes.	Chaux	Terre calcaire, chaux.
	Magnéſie	Magnéſie, baſe du ſel d'epſom.
	Baryte	Barote, terre peſante.
	Alumine	Argile, terre de l'alun, baſe de l'alun.
	Silice	Terre ſiliceuſe, terre vitrifiable.

Lavoisier's Table of the Elements

Robert Bunsen (1811-99) & Gustav Kirchoff (1824-87), 1859 ff, sun (etc) contains same elements as earth

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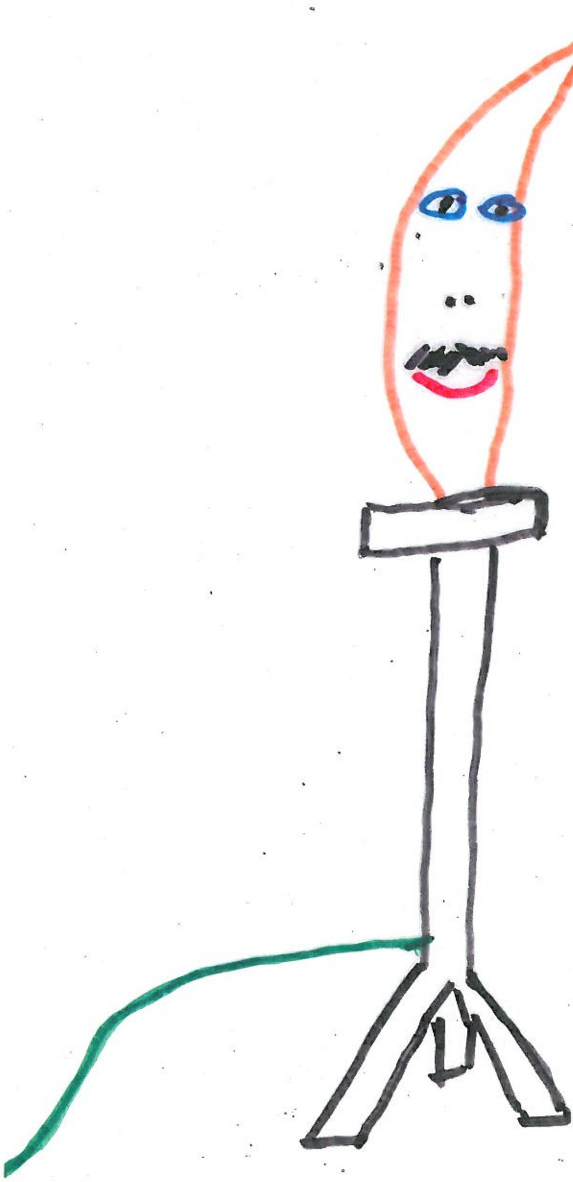

КИРХГОФ Густав Роберт
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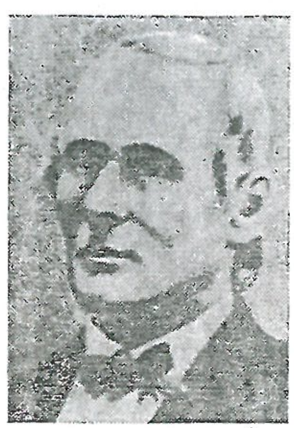

АНГСТРЕМ (Онгстрём)
Андерс Йонас
(13.VIII 1814—21.VI 1874)

Fig. 5. Cecilia Payne behind
Everett House 1924

THE CHEMICAL NEWS.

Vol. LXI. No. 1575.

ON THE GENESIS OF ELEMENTS.

By H. M. VERNON.

(c.1800)

Since the time when Prout first formulated his hypothesis of the genesis of the elements from the primordial atom, there has always been a feeling in the minds of chemists that this hypothesis may possibly in some future time be verified experimentally, at least to a certain degree. This feeling has been strengthened during the last few years by the discoveries of Crookes and other chemists, of what have been termed the meta-elements. Crookes, starting from a specimen of mineral supposed to contain only one or two rare earths, has succeeded by a laborious process of fractionation in resolving one of these earths, supposed to be the oxide of a single element, into several other earths, all of which have properties almost exactly similar, and only capable of being distinguished in some cases by the difference in their colours or by the difference of a single line in their spectra. These earths are the oxides of elements of scarcely perceptibly different atomic weights, for all of which it would not seem possible to provide a place in the table of elements arranged according to Mendeleeff's Periodic Law.

Arguing from these discoveries, Crookes asks whether it may not be possible by suitable methods of fractionation to separate many, if not all, of the rest of the so-called elements into a number of other elements almost exactly similar in properties and in atomic weights, and thus to obtain an almost infinite series of elements, the properties of which gradually change in regular order as they pass through the cycles of the series of elements arranged according to the periodic law.

Many almost insurmountable difficulties, which it will be unnecessary to enumerate, have been brought against this chain of reasoning by various chemists. This hypothesis, being for the present, at least, therefore considered unacceptable, we come to the question as to whether there is no other hypothesis that has the same end in view which is capable of being formulated, such that may appeal more readily to the minds of chemists. It is with this object in view that these few ideas have been brought forward.

At the beginning of the universe we may consider it very probable that there existed only the primordial atom, which, as in the course of ages, became gradually cooled down, united amongst itself to form the complete cycle of elements as known to us at the present day. Those elements most stable as regards heat would first be formed as this process of cooling went on, while those least stable with regard to heat would be formed last, all elements but the first being formed by the addition of other

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table:—

Groups.	1.	2.	3.
1.	H		
2.	Li	Be	
3.	Na	Mg	Al
4.	K	Ca	—
5.	Cu	Zn	
6.	Rb	Sr	Y
7.	Ag	Cd	In
8.	Cs	Ba	Ce
			E
9.	—	—	
10.			
11.	—	—	—

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large number of atomic weight determinations during this period. Very many other chemists, among them Gmelin, Erdmann, and Marchand, were also numbered among Prout's supporters. On the other hand, Stas, who in the beginning tried to aid Dumas in the revival of Prout's hypothesis, afterward designated it as a pure fiction, and Berzelius at all times adhered to the view that the exact atomic weights could not be determined except by experiment.

The prejudice which existed a few years ago against Prout's idea is well shown by a quotation from von Meyer's History of Chemistry, printed in 1906.

"During the period in which Davy and Gay-Lussac were carrying on their brilliant work, and before the star of Berzelius had attained to its full luster, a literary chemical event occurred which made a profound impression upon nearly all the chemists of that day, *viz.*, the advancement of Prout's hypothesis. This was one of the factors which materially depreciated the atomic doctrine in the eyes of many eminent investigators. On account of its influence upon the further development of the atomic theory this hypothesis must be discussed here, although it but seldom happens that an idea from which important theoretical conceptions sprang, originated in so faulty a manner as it did."

Prout's work was not, as the above quotation infers, entirely "literary," for he made a large number of experimental determinations for use in his calculations of the specific gravity of the various elements, which he assumed to exist in the gaseous form. His experiments were, according to his own statements, somewhat crude, but he also made use of the more accurate data obtained by Gay-Lussac, and his work was based upon the volume relations of gases as discovered by the French investigator.

Exactly the form in which the numerical part of Prout's hypothesis should be expressed in terms of modern atomic weights, it is difficult to say, but the principal point is that his atomic weights, which, however, are not comparable with those now used, were expressed in whole numbers, as given below in two columns taken from his table:

TABLE I.—PROUT'S TABLE OF THE MORE ACCURATELY DETERMINED ATOMIC WEIGHTS.

Element.	Sp. gr.	Atomic weight, 2 vols. of hydrogen being 1.
H	1	1
C	6	6
N	14	14
P	14	14
O	16	8
S	16	16
Ca	20	20
Na	24	24
Fe	28	28
Zn	32	32
Cl	36	36
K	40	40
Ba	70	70
[illegible]	[illegible]	[illegible]

The atomic weights thus given by Prout are within a few units of the modern values in the case of the univalent atoms and for nitrogen; but the values given for the atoms of higher valence, with the exception of nitrogen, are approximately half the present values. This would mean that according to Prout's system, since the atomic weights he gives are whole numbers, the atomic weights of the present system should be divisible by two for the atoms of higher valence, which is equivalent to the use of the hydrogen molecule instead of the atom as a unit. In this connection it may be noticed that his atomic weights are taken on the basis of "2 volumes of hydrogen being 1."

Thus, from a numerical standpoint, Prout's hypothesis does not seem to mean what is usually supposed. Expressed in terms of the composition of what he considered to be complex atoms, it is given below in his own words:

"If the views we have endeavored to advance be correct, we may also consider the πρώτη ὕλη of the ancients to be realized in hydrogen, an opinion by the way, not altogether new. If we actually consider this to be the case, and further consider the specific gravities of bodies in their gaseous state to represent the number of volumes condensed into one; or, in other words, the number of the absolute weight of a single volume of the first matter which they contain, which is extremely probable, multiples in weight must also indicate multiples in volume, and *vice versa;* and the specific gravities, or absolute weights of all bodies in the gaseous state, must be multiples of the specific gravity or absolute weight of the first matter, because all bodies in a gaseous state which unite with one another, unite with reference to their volume."

While it is true that Prout had at the time when he presented it, no real foundation for his ideas, more accurate work, while it proved his system to be invalid from a purely numerical standpoint, at the same time established the fact that the atomic weights of the lighter elements, on the hydrogen basis, are much closer to whole numbers than would be likely to result from any entirely accidental method of distribution. Thus the deviations of the lighter elements are small, as will be seen by the following table:

Element.	At. wt. H = 1.	Deviation from a whole number.
He	3.97	0.03
Li	6.89	0.11
Be	9.03	0.03
B	10.91	0.09
C	11.91	0.09
N	13.90	0.10
O	15.88	0.12
F	18.85	0.15

The average of these deviations is 0.09 unit, while the theoretical deviation on the basis that the values for the atomic weights are entirely accidental, is 0.25 unit. If the first seventeen elements are used in the calculation, the average deviation is found to be 0.15 unit, while the re-of atoms. The accompanying diagram (Fig. 1) represents the relative abundance of the different types of atoms composing the first 39 elements. Although these number less than half the elements known yet, owing to the great preponderance of the lighter elements in terrestrial matter, they represent a surprisingly large percentage, being more than 99·8 by weight of all such matter available for chemical analysis.

The mass-number of each species of atom, that is to say its whole number atomic weight or the number of protons in its nucleus, is plotted against the logarithm to base 10 of the total number of gram-atoms on the earth. The latter figure is arrived at in the following manner. The earth is assumed for the purposes of this calculation to consist of a lithosphere of mass $5\cdot98 \times 10^{27}$ gm. having the average composition of the igneous rocks, a hydrosphere of mass $1\cdot45 \times 10^{24}$ gm. of water, and an atmosphere of mass $5\cdot29 \times 10^{21}$ gm. of ordinary air. That the unknown interior of the earth has the same chemical composition as the deeper parts of its outer crust is, of course, flagrantly improbable, but to leave it out of the calculation altogether might give the hydrosphere and atmosphere undue prominence. The average chemical composition of the igneous rocks is calculated in gram-atoms from the percentage composition given in the admirable report on the subject by Clarke and Washington (No. 462 Geophysical Laboratory, Washington; May 1922). Ramsay's and Claude's figures are taken for the atmosphere. In the case of a complex element, the proportion of its various isotopes, when not otherwise ascertainable, is estimated from the intensity of their lines on its mass-spectrum. This rough method is sufficient for the diagram, for which no great accuracy is claimed. Only the roughest estimates are available for the percentages of the rarer ... rocks.

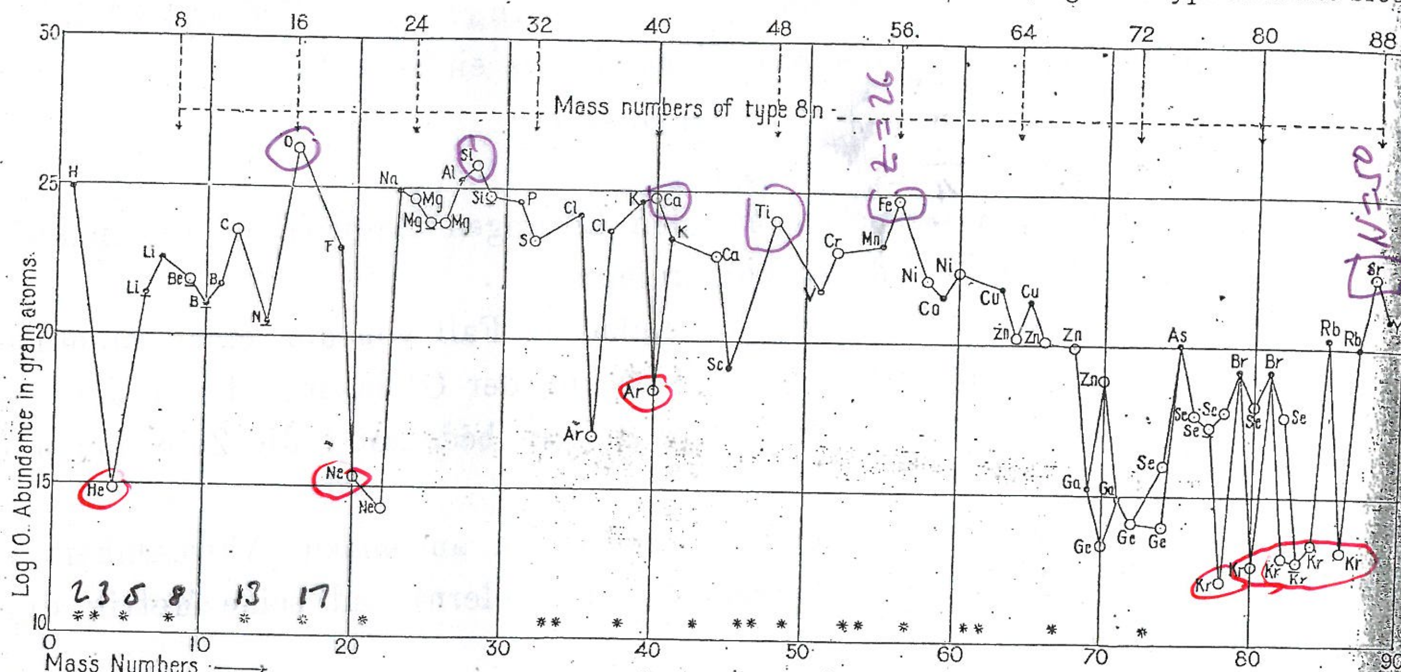

FIG. 1.—Relative abundance of atomic species of the first 39 elements.
○ Even atomic number 41 } Total, 69 species.
● Odd atomic number 28
✳ Missing or doubtful mass numbers.

M ~ 2.5 ~ Eddington's ⊙

are considering $1\cdot73 \times 10^{26}$ gram-atoms containing very nearly 10^{50} of type O^{16} in all. Of the next most abundant type, Si^{28}, there are about one-third that number. The types belonging to odd and even atomic number are distinguished from each other and a continuous connecting line is drawn. In the case of isobaric pairs this line is duplicated, making the diagram somewhat complicated in the region of krypton. It is of interest to note that the contribution of hydrogen atoms from the sea is barely distinguishable on this diagram, while that of oxygen atoms from the sea and air combined is entirely insignificant.

The preponderance of elements of even atomic number is well shown by the peaks 8 O^{16}, 14 Si^{28}, 20 Ca^{40}, 22 Ti^{48}, 26 Fe^{56}, 38 Sr^{88}, which have an enormous significance on a log scale of this kind. The outstanding importance of atomic weights of type 8n is also brought out clearly. The appearance of more uniform distribution among the odd atomic numbers than among the even ones is probably largely fictitious, and due to the method of calculating the abundance of the inert gases. Attention may be directed to the scarcity of those types which contain an odd number of electrons in the nucleus. These only number 7 out of a total of 69, and 4 of these, including all those of even atomic number, occur below atomic number 8.

The curve was originally drawn in the hope that it might afford some evidence as to the relative stability of nuclei during the evolution of the atoms. In this respect its irregularity is rather disappointing, but consideration of it raises many points of interest. The one with which this article is particularly concerned is perhaps the most obvious of all; that is, the extreme contrast between the range of abundance exhibited among the different isotopes of one element and that shown among the elements themselves; *e.g.* there are ... three Cl^{35} atoms to one Cl^{37} and about tw...

Zur Wellentheorie der Materie.

Von **G. Gamow** und **D. Iwanenko** in Leningrad.

Mit 1 Abbildung. (Eingegangen am 19. September 1926.)

Es sind einige, das Materieproblem betreffende Folgerungen der fünfdimensionalen Geometrie gegeben.

Die Tendenz, die Materie als einen komplizierten Wellenvorgang aufzufassen, ist in den Arbeiten von de Broglie[1]) zu einem klaren Programm ausgebildet. Die dazu nötigen mathematischen Methoden wurden bekanntlich von Schrödinger[2]) ausgearbeitet. Statt der gewöhnlichen Hamiltonschen partiellen Differentialgleichung wurde von ihm eine spezielle Wellengleichung eingeführt. Wie O. Klein[3]) und V. Fock[4]) zeigten, kann die Schrödingersche Wellengleichung bei Einführung der fünften Koordinate in die einfache Form

$$\Box \psi = 0 \tag{1}$$

gebracht werden.

Man kann versuchen, aus den Lösungen dieser Gleichung materiellpunktähnliche Gebilde zu konstruieren.

§ 1. Wir wollen hier den einfachen Fall von nur einer räumlichen Koordinate x behandeln und die Lösung der Gleichung (1) in dem dreidimensionalen $(x\,t\,p)$-Raum suchen. Hier bedeutet t die Zeit und p die neue Koordinate.

Unseren Raum werden wir euklidisch annehmen (Abwesenheit von Gravitations- und elektromagnetischen Feldern) und seine Metrik durch die Form

$$d s^2 = d x_0^2 + d x_1^2 - d x_2^2 \tag{2}$$

bestimmen, wo

$$x_0 = \frac{1}{m c} p; \quad x_1 = x; \; x_2 = c t \quad \text{ist.} \tag{3}$$

Hier ist m die Elementarmasse und c die Grundgeschwindigkeit.

Wir fordern[5]), daß die Lösungen der Gleichung (1) in bezug auf die Koordinate p rein periodisch mit der Planckschen Konstante h als Periode sein müssen.

---

[1]) de Broglie, Ann. de phys. (10) **3**, 22, 1925.

[2]) E. Schrödinger, Ann. d. Phys. **79**, 361, 489, 1926.

[3]) O. Klein, ZS. f. Phys. **37**, 895, 1926.

[4]) V. Fock, ZS. f. Phys. **39**, 226, 1926. In dieser Notiz behalten wir die Bezeichnungen von V. Fock bei. Herrn V. Fock, der uns seine Arbeit in der Korrektur zur Verfügung stellte, sind wir zum größten Dank verpflichtet.

[5]) V. Fock, l. c.

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the curves
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inconvenient.

6. A different anamorphosis yields an alignment diagram which may perhaps be more convenient, particularly for computing the uniform pressure which any rectangular pane will bear. Equation (1) may be written

$$\begin{vmatrix} a^2/(a^2+c^2) & 0 & 1 \\ 0 & b^2/(b^2+c^2) & 1 \\ \dfrac{2ft^2}{4ft^2+pkc^2} & \dfrac{2ft^2}{4ft^2+pkc^2} & 1 \end{vmatrix} = 0,$$

which, in cartesian coordinates, is the condition of collinearity of the points

$$\left(\frac{a^2}{a^2+c^2},\ 0\right),\quad \left(0,\ \frac{b^2}{b^2+c^2}\right),\ \text{and}\ \left(\frac{2ft^2}{4ft^2+pkc^2},\ \frac{2ft^2}{4ft^2+pkc^2}\right),$$

where c is an arbitrary constant.

The alignment diagram shown in fig. 2 is for the value $c=5$ ft., and shows the uniform pressure which a pane of 3/16 in. plate glass will bear.

Building Research Station,
Garston, Hertfordshire.

Phil Mag 1934

LXXV. *Radioactivity and Nuclear Synthesis.* By HAROLD J. WALKE, *M.Sc., Demonstrator in Physics, Washington Singer Laboratories, University College, Exeter* †.

FEET

I. *Introduction.*

IT has been suggested in a previous paper ‡ that the elements may be considered to have been synthesized in nebulæ and stars from a primary distribution of neutons constituting a gravitating gas of zero atomic number-neuton. It has further been suggested, in view of present experimental evidence, that in none of the synthesis processes are neutrons created or destroyed, it being postulated that the total number of neutrons in the universe is fixed, this number being a fundamental cosmical constant.

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a and b,
a^2, $1/b^2$,

† Communicated by Professor F. H. Newman, D.Sc.
‡ Walke, in the press.

1st GG paper on n's 1985 Ohio J.S.

already discussed probably indicates that missing isotopes are radioactive, as it can be shown that neutron capture, whether followed by the emission of nuclear components or not, produces in many cases "missing" isotopes and that all cases of radioactivity observed by Fermi are explicable on this theory. Many of the elements of odd atomic number consist of pairs of isotopes differing by two units of mass, though several consist of only one isotope. It is suggested that the missing mass number between the two isotopes is that of a β-radioactive isotope, and in many cases the addition of a neutron to the lighter isotope of such a pair produces this radioactive isotope. In most cases, too, the addition of a neutron to the heavier isotope of a pair forms another β-radioactive isotope, so that, as Fermi has observed, β-ray activity with two periods results from the interaction of neutrons with some elements.

Thus, cosmically, the synthesis from copper to zinc results from the unstable isotopes Cu^{64}_{29} and Cu^{66}_{29} produced when the stable isotopes capture a neutron. The other zinc isotopes are then produced by neutron capture, the relative abundance of the group of isotopes being determined by the stability of the separate isotopes under the continual bombardment by the ions present, and by the formation of these isotopes from both lighter and heavier elements. Zn^{69}_{30} is missing, and the last stable zinc isotope is Zn^{70}_{30}. Synthesis to gallium therefore proceeds as follows :—

$$Zn^{69}_{30} \rightarrow Ga^{69}_{31} + \overset{\nearrow}{\beta}\ ;\ Zn^{71}_{30} \rightarrow \overset{\nearrow}{Ga^{71}_{31}} + \overset{\nearrow}{\beta},$$

the unstable zinc isotopes being produced by the capture of a neutron by Zn^{68}_{30} and Zn^{70}_{30} respectively. It is significant that Fermi has observed β-radioactivity with both copper and zinc bombarded by neutrons.

The missing gallium isotopes Ga^{70}_{31} and Ga^{72}_{31} are β-ray links in the evolution of the elements by neutron capture and radioactive synthesis producing the stable isotopes Ge^{70}_{32} and Ge^{72}_{32}. The other germanium isotopes result from neutron absorption, the last stable isotope having mass number 76. Ge^{75}_{32} is missing, and this isotope it is postulated is radioactive to produce As^{75}_{33}. Arsenic is a single element, so that As^{76}_{33} resulting from As^{75}_{33} by neutron capture produces Se^{76}_{34}. In addition, Ge^{77}_{32} produced by the addition of a neutron to Ge^{76}_{32} is β radioactive, and since As^{77}_{33} is also missing it is probable that the double β-ray synthesis

$$Ge^{77}_{32} \rightarrow \beta \rightarrow As^{77}_{33} \rightarrow \beta \rightarrow Se^{77}_{34}$$

takes place. It is significant that selenium has an isotope of mass 74 which does not fit in with this suggested progressive synthesis. It is perhaps possible that Ge^{73}_{32} is a β-ray emitter and that arsenic possesses a second isotope of mass 73 which exists in small abundance and has not been detected. In consequence the β-ray activity of As^{74}_{33} would produce Se^{74}_{34}. This is, however, doubtful, in spite of the fact that the Committee on Atomic Weights of the International Union of Chemistry has recently † altered the atomic weight of arsenic to 74·91, and it is more probable that Se^{74}_{34} is produced by some secondary process and that it does not arise in the direct synthesis process.

β process

The missing selenium isotopes Se^{79}_{34} and Se^{81}_{34} are β-ray emitters and produce Br^{79}_{35} and Br^{81}_{35}, the unstable isotopes being produced when Se^{78}_{34} and Se^{80}_{34} capture a neutron. Similarly, the missing bromine isotopes Br^{80}_{35} and Br^{82}_{35} are the synthesis links producing Xe^{80}_{36} and Xe^{82}_{36}. The other xenon isotopes are produced by the successive addition of neutrons to these nuclei. It is difficult, however, on this hypothesis to account for the isotope of mass 78 which exists in slight abundance unless the following action occurs :—

$$Br^{81}_{35} \rightarrow \beta \rightarrow \overset{*}{Kr}{}^{82}_{36} \rightarrow \alpha \rightarrow \overset{*}{Se}{}^{78}_{34} \rightarrow \beta \rightarrow Br^{78}_{35} \rightarrow \beta \rightarrow Kr^{78}_{36},$$

the nucleus $\overset{*}{Kr}{}^{82}_{36}$ formed in an excited state occasionally emitting an α-particle instead of γ-radiation, the $\overset{*}{Se}{}^{78}_{34}$ nucleus so formed being excited and emitting β-rays as shown.

The missing krypton isotopes Kr^{85}_{36} and Kr^{87}_{36} are β-radioactive and produce the isotopes Rb^{85}_{37} and Rb^{87}_{37}, the unstable isotopes resulting from Kr^{84}_{36} and Kr^{86}_{36} by the addition of neutrons. In the case of rubidium it seems definite that Rb^{87}_{37} is radioactive and emits β-radiation, so

† Journ. Chem. Soc., April 1934.

not certain, that comparatively minor alterations would strengthen it very considerably. For the present, the attempt has been made to rely as far as possible on assumptions which already have some physical support; arbitrary hypotheses are avoided until it becomes clear that even the broadest study is held up for lack of one.

2. THE THEORY OF REGENERATIVE SYNTHESIS

It is well known that the maximum possible life of the universe is much shorter if stellar energy is due to transmutation of the elements than if it is due to total annihilation. In fact, it is definitely too short to fit some theories of stellar dynamics, associated mainly with the name of Jeans, which, to say the least, have never been disproved. We shall return to this question later.[1] For the majority of other views, synthesis, provided hydrogen is consumed in it, furnishes an adequate, if scarcely a very liberal, time-scale;[2] if the element consumed is not hydrogen, the scale will be shortened from six to ten times at the least, and much more in most cases, since all other possible transformations upward or downward from known elements involve so much less percentage change of mass.

Russell has recently shown that the percentage of hydrogen in stars is probably very much greater even at the present time than had generally been supposed; in the sun's atmosphere, for example, sixty out of every sixty-five atoms are hydrogen. Since in addition the hydrogen nucleus is probably much simpler than any other, it seems very reasonable to assume that in its initial state any star, or indeed the entire universe, was composed solely of hydrogen; the small amount of angular momentum possessed by individual stars indicates that if this hydrogen was originally diffuse there was probably also very little small-scale motion in it; and the assumption that it was also cold is, though unimportant, at least as attractive as any other. The initial state of the universe thus becomes one of very remarkable simplicity, and we hope to show that the present complexity both of stars and of chemical elements could develop from this state by a self-regulating process.

At the outset there is one obvious difficulty that has been noticed by nearly every student of the question; the simplest direct synthesis

[1] §8, A, i.

[2] Eddington, *op. cit.*, p. 293.

THE END GAME

B^2FH 1957, sure enough you can build everything from hydrogen (Prout was right)

Beatrice Muriel Hill Tinsley 1967, a galaxy made of baryons can describe chemical evoln, residual gas fraction, luminosity vs time etc
Still remarkably true (Matteuchi book 2012)

Yale 1977, Evolution of galaxies & stellar populations. Chemical evoln. still baryons. Baryonic, non-dissipative DM for halos in galaxy mergers (brown dwarfs??)

Super Massive Objects
Fowler (+ Wheeler) 60th birthdays

1971

M. Angel, A. King, J. Pringle, T. Weekes, M. Pollock, R. Carswell, K. Fricke, P. Martin, F. Dilke, I. Roxburgh, A. Cameron, D. Arnett, J. Bardeen, K. Lang, V. Trimble, S. Woosley, R. Talbot

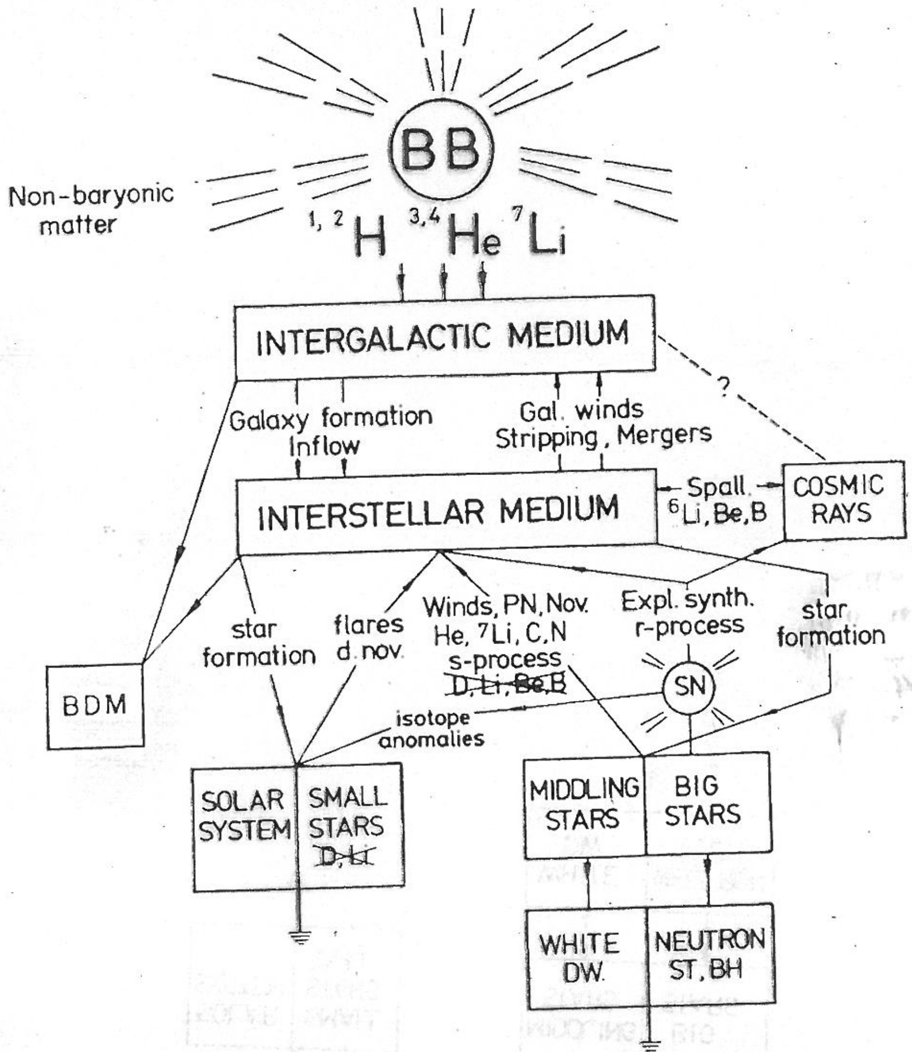
Yale Observatory

1880s

1870s

This bit left out

Fig. 1.1 shows a general scheme or 'creation myth' [redacted] as first set out in plausible detail by E.M. & G.R. Burbidge, W.A. Fowler and F. Hoyle (usually abbreviated to B^2FH) in a classic article in *Rev. Mod. Phys.* in 1957 and independently by A.G.W. Cameron in an Atomic Energy of Canada report in the same year.



Conclasion:

The End