

# Margaret Peachey Burbidge (1919)

1939

*“non si svolsero cerimonie per la mia laurea, nell'estate del '39 era ovvio che l'Inghilterra andava incontro alla guerra con la Germania.”*

*“Avendo letto un annuncio su The Observer per una ricerca di personale all'Università Carnegie per il Mt. Wilson Observatory feci domanda”*

*“La lettera di rifiuto diceva semplicemente che i posti al Carnegie Fellowship erano riservati agli uomini. Apparentemente alle donne non era concesso l'uso dei telescopi di Mt. Wilson”*



# REVIEWS OF MODERN PHYSICS

VOLUME 29, NUMBER 4

OCTOBER, 1957

## Synthesis of the Elements in Stars\*

E. MARGARET BURRIDGE, R. BURRIDGE, WILLIAM A. FOWLER, AND F. HOYLE

*California Radiation Laboratory, California Institute of Technology, and  
Mount Wilson and Palomar Observatories, Carnegie Institution of Washington,  
California Institute of Technology, Pasadena, California*

"It is the stars, The stars above us, govern our conditions";  
(*King Lear*, Act IV, Scene 3)

but perhaps

"The fault, dear Brutus, is not in our stars, But in ourselves,"  
(*Julius Caesar*, Act I, Scene 2)

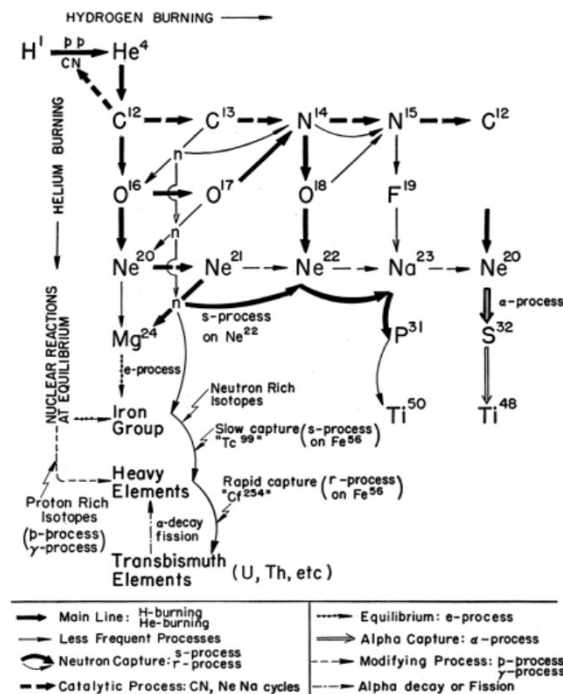
### TABLE OF CONTENTS

|  | Page |
|--|------|
| I. Introduction.....   | 548  |
| A. Element Abundances and Nuclear Structure.....   | 548  |
| B. Four Theories of the Origin of the Elements.....  | 550  |
| C. General Features of Stellar Synthesis.....  | 550  |
| II. Physical Processes Involved in Stellar Synthesis, Their Place of Occurrence, and the Time-Scales Associated with Them..... | 551  |
| A. Modes of Element Synthesis.....   | 551  |
| B. Method of Assignment of Isotopes among Processes (i) to (viii).....   | 553  |
| C. Abundances and Synthesis Assignments Given in the Appendix.....   | 555  |
| D. Time-Scales for Different Modes of Synthesis.....   | 556  |
| III. Hydrogen Burning, Helium Burning, the $\alpha$ Process, and Neutron Production.....                                       | 559  |
| A. Cross-Section Factor and Reaction Rates.....  | 559  |
| B. Pure Hydrogen Burning.....  | 562  |
| C. Pure Helium Burning.....  | 565  |
| D. $\alpha$ Process.....   | 567  |
| E. Succession of Nuclear Fuels in an Evolving Star.....  | 568  |
| F. Burning of Hydrogen and Helium with Mixtures of Other Elements; Stellar Neutron Sources.....                                | 569  |
| IV. $e$ Process.....   | 577  |
| V. $s$ and $r$ Processes: General Considerations.....  | 580  |
| A. "Shielded" and "Shielding" Isobars and the $s$ , $r$ , $p$ Processes.....   | 580  |
| B. Neutron-Capture Cross Sections.....   | 581  |
| C. General Dynamics of the $s$ and $r$ Processes.....  | 583  |
| VI. Details of the $s$ Process.....  | 583  |

\* Supported in part by the joint program of the Office of Naval Research and the U. S. Atomic Energy Commission.

547

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|  |  |                       |    |                   |     |     |     |     |     |     |     |     |     |          |    |    |    |             |    |
|--|--|-----------------------|----|-------------------|-----|-----|-----|-----|-----|-----|-----|-----|-----|----------|----|----|----|-------------|----|
|  |  | Alkaline earth metals |    |                   |     |     |     |     |     |     |     |     |     |          |    |    |    | Noble gases |    |
|  |  | 1A                    | 2A |                   |     |     |     |     |     |     |     |     |     | Halogens |    |    |    | 18A         |    |
|  |  | 1                     | 2  |                   |     |     |     |     |     |     |     |     |     | 13       | 14 | 15 | 16 | 17          | 2  |
|  |  | H                     | He |                   |     |     |     |     |     |     |     |     |     | 3A       | 4A | 5A | 6A | 7A          | 8A |
|  |  | 3                     | 4  |                   |     |     |     |     |     |     |     |     |     | 5        | 6  | 7  | 8  | 9           | 10 |
|  |  | Li                    | Be |                   |     |     |     |     |     |     |     |     |     | B        | C  | N  | O  | F           | Ne |
|  |  | 11                    | 12 | 3                 | 4   | 5   | 6   | 7   | 8   | 9   | 10  | 11  | 12  | 13       | 14 | 15 | 16 | 17          | 18 |
|  |  | Na                    | Mg | Transition metals |     |     |     |     |     |     |     |     |     | Al       | Si | P  | S  | Cl          | Ar |
|  |  | 19                    | 20 | 21                | 22  | 23  | 24  | 25  | 26  | 27  | 28  | 29  | 30  | 31       | 32 | 33 | 34 | 35          | 36 |
|  |  | K                     | Ca | Sc                | Ti  | V   | Cr  | Mn  | Fe  | Co  | Ni  | Cu  | Zn  | Ga       | Ge | As | Se | Br          | Kr |
|  |  | 37                    | 38 | 39                | 40  | 41  | 42  | 43  | 44  | 45  | 46  | 47  | 48  | 49       | 50 | 51 | 52 | 53          | 54 |
|  |  | Rb                    | Sr | Y                 | Zr  | Nb  | Mo  | Tc  | Ru  | Rh  | Pd  | Ag  | Cd  | In       | Sn | Sb | Te | I           | Xe |
|  |  | 55                    | 56 | 57                | 72  | 73  | 74  | 75  | 76  | 77  | 78  | 79  | 80  | 81       | 82 | 83 | 84 | 85          | 86 |
|  |  | Cs                    | Ba | La*               | Hf  | Ta  | W   | Re  | Os  | Ir  | Pt  | Au  | Hg  | Tl       | Pb | Bi | Po | At          | Rn |
|  |  | 87                    | 88 | 89                | 104 | 105 | 106 | 107 | 108 | 109 | 110 | 111 | 112 |          |    |    |    |             |    |
|  |  | Fr                    | Ra | Ac†               | Rf  | Db  | Sg  | Bh  | Hs  | Mt  | Uun | Uuu | Uub |          |    |    |    |             |    |

|              |    |    |    |    |    |    |    |    |    |    |
|--------------|----|----|----|----|----|----|----|----|----|----|
| *Lanthanides | 58 | 59 | 60 | 61 | 62 | 63 | 64 | 65 | 66 | 67 |
|              | Ce | Pr | Nd | Pm | Sm | Eu | Gd | Tb | Dy | Ho |
| †Actinides   | 90 | 91 | 92 | 93 | 94 | 95 | 96 | 97 | 98 | 99 |
|              | Th | Pa | U  | Np | Pu | Am | Cm | Bk | Cf | Es |

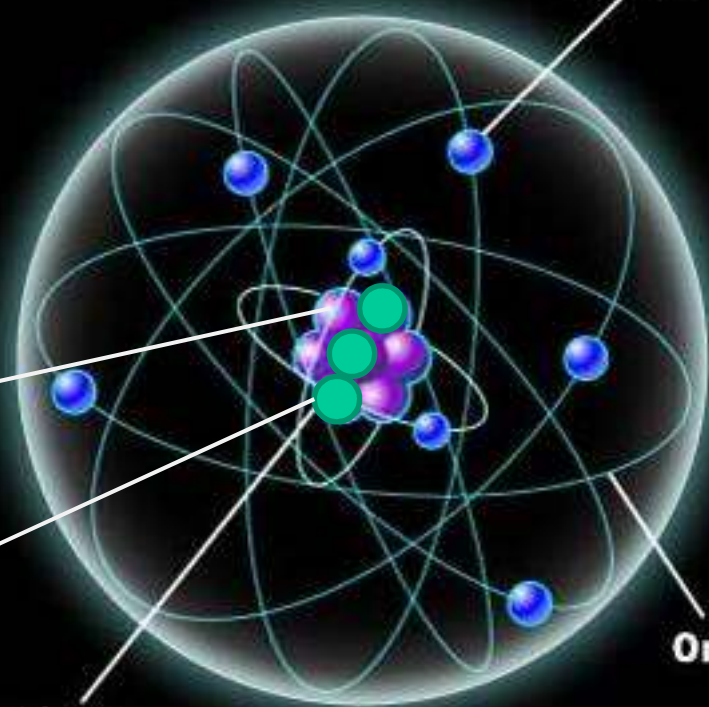
neutroni

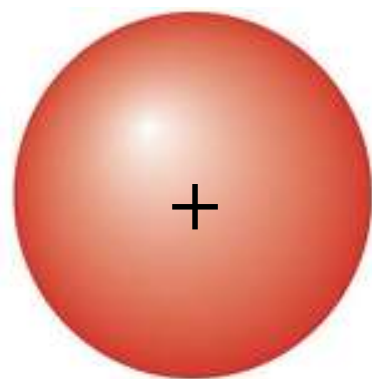
protoni

Nucleus

Electron

Orbit





protone

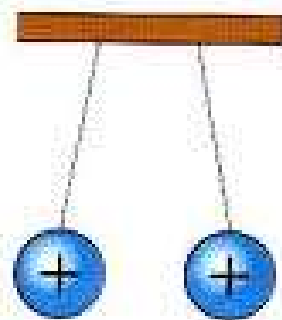
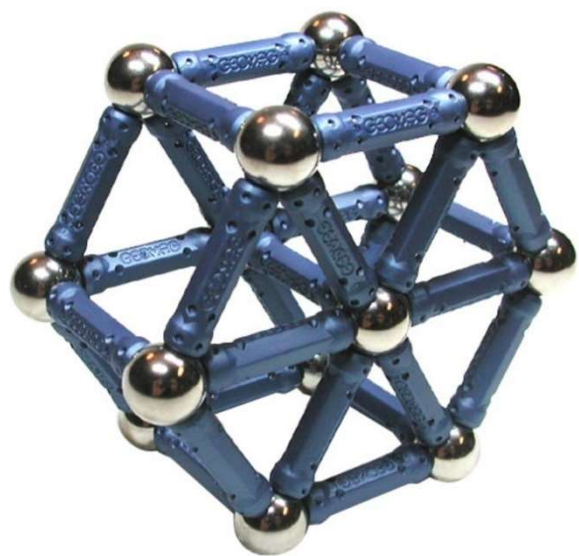


neutrone

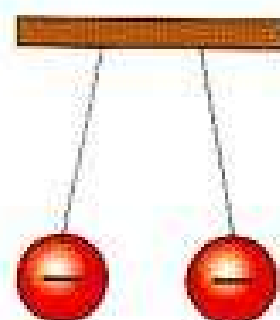
-



elettrone



si respingono



si respingono



si attraggono



# La materia è composta da:

La materia è composta da:

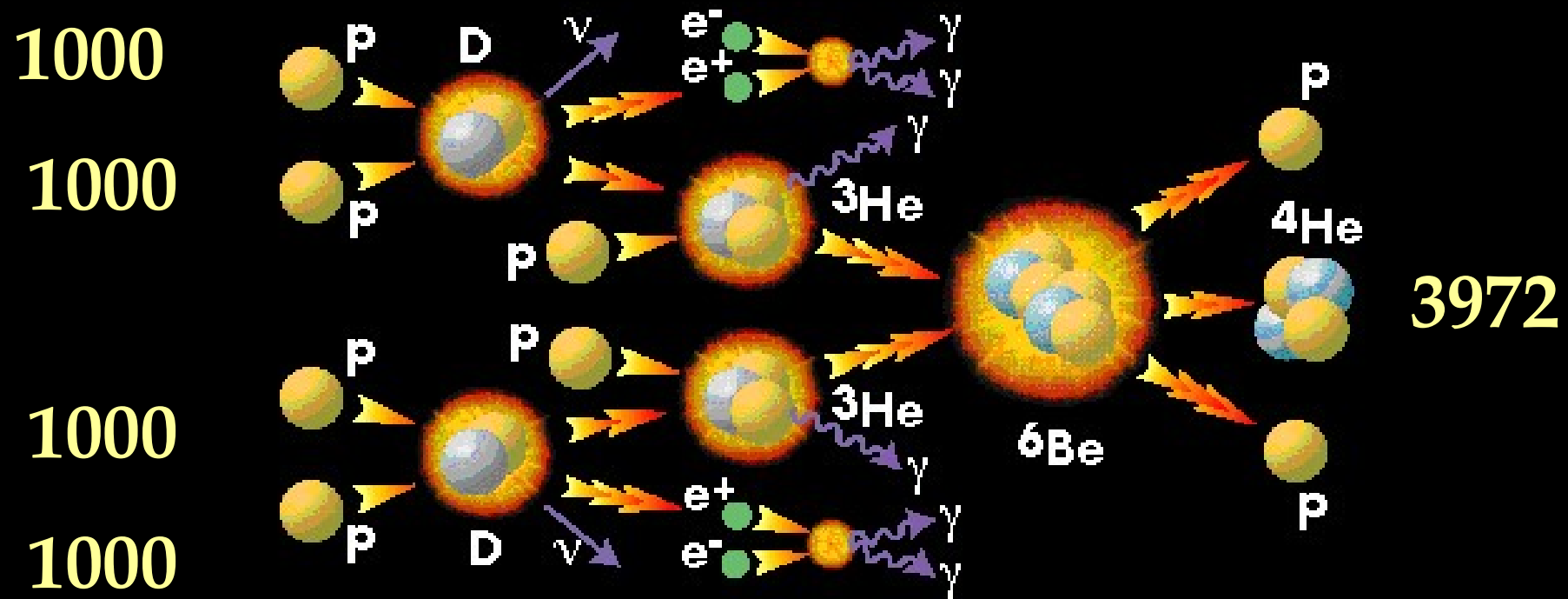
|                            |                   |           |           |           |           |           |           |           |            |            |            |          |          |          |          |          |          |                              |          |          |          |          |          |    |          |          |          |          |          |          |          |          |
|----------------------------|-------------------|-----------|-----------|-----------|-----------|-----------|-----------|-----------|------------|------------|------------|----------|----------|----------|----------|----------|----------|------------------------------|----------|----------|----------|----------|----------|----|----------|----------|----------|----------|----------|----------|----------|----------|
|                            |                   |           |           |           |           |           |           |           |            |            |            |          |          |          |          |          |          | Noble gases<br>↓<br>18<br>8A |          |          |          |          |          |    |          |          |          |          |          |          |          |          |
| Alkaline earth metals<br>↓ |                   |           |           |           |           |           |           |           |            |            |            |          |          |          |          |          |          | Halogens<br>↓<br>17<br>7A    |          | 2        |          |          |          |    |          |          |          |          |          |          |          |          |
| 1<br>1A                    | 2<br>2A           |           |           |           |           |           |           |           |            |            |            |          |          |          |          |          |          | 13<br>3A                     | 14<br>4A | 15<br>5A | 16<br>6A | 17<br>7A | 18<br>8A |    |          |          |          |          |          |          |          |          |
| 1<br>H                     | 2<br>He           |           |           |           |           |           |           |           |            |            |            |          |          |          |          |          |          | 5<br>B                       | 6<br>C   | 7<br>N   | 8<br>O   | 9<br>F   | 10<br>Ne |    |          |          |          |          |          |          |          |          |
| Alkali metals              | 3<br>Li           | 4<br>Be   |           |           |           |           |           |           |            |            |            |          | 11<br>Na | 12<br>Mg | 3        | 4        | 5        | 6                            | 7        | 8        | 9        | 10       | 11       | 12 | 13<br>Al | 14<br>Si | 15<br>P  | 16<br>S  | 17<br>Cl | 18<br>Ar |          |          |
|                            | Transition metals |           |           |           |           |           |           |           |            |            |            |          |          |          |          |          |          |                              |          |          |          |          |          |    |          |          | 13<br>Al | 14<br>Si | 15<br>P  | 16<br>S  | 17<br>Cl | 18<br>Ar |
|                            | 19<br>K           | 20<br>Ca  | 21<br>Sc  | 22<br>Ti  | 23<br>V   | 24<br>Cr  | 25<br>Mn  | 26<br>Fe  | 27<br>Co   | 28<br>Ni   | 29<br>Cu   | 30<br>Zn | 31<br>Ga | 32<br>Ge | 33<br>As | 34<br>Se | 35<br>Br | 36<br>Kr                     |          |          |          |          |          |    |          |          |          |          |          |          |          |          |
|                            | 37<br>Rb          | 38<br>Sr  | 39<br>Y   | 40<br>Zr  | 41<br>Nb  | 42<br>Mo  | 43<br>Tc  | 44<br>Ru  | 45<br>Rh   | 46<br>Pd   | 47<br>Ag   | 48<br>Cd | 49<br>In | 50<br>Sn | 51<br>Sb | 52<br>Te | 53<br>I  | 54<br>Xe                     |          |          |          |          |          |    |          |          |          |          |          |          |          |          |
|                            | 55<br>Cs          | 56<br>Ba  | 57<br>La* | 72<br>Hf  | 73<br>Ta  | 74<br>W   | 75<br>Re  | 76<br>Os  | 77<br>Ir   | 78<br>Pt   | 79<br>Au   | 80<br>Hg | 81<br>Tl | 82<br>Pb | 83<br>Bi | 84<br>Po | 85<br>At | 86<br>Rn                     |          |          |          |          |          |    |          |          |          |          |          |          |          |          |
| 87<br>Fr                   | 88<br>Ra          | 89<br>Ac† | 104<br>Rf | 105<br>Db | 106<br>Sg | 107<br>Bh | 108<br>Hs | 109<br>Mt | 110<br>Uun | 111<br>Uuu | 112<br>Uub |          |          |          |          |          |          |                              |          |          |          |          |          |    |          |          |          |          |          |          |          |          |

\*Lanthanides

†Actinides

|          |          |          |          |          |          |          |          |          |          |           |           |           |           |
|----------|----------|----------|----------|----------|----------|----------|----------|----------|----------|-----------|-----------|-----------|-----------|
| 58<br>Ce | 59<br>Pr | 60<br>Nd | 61<br>Pm | 62<br>Sm | 63<br>Eu | 64<br>Gd | 65<br>Tb | 66<br>Dy | 67<br>Ho | 68<br>Er  | 69<br>Tm  | 70<br>Yb  | 71<br>Lu  |
| 90<br>Th | 91<br>Pa | 92<br>U  | 93<br>Np | 94<br>Pu | 95<br>Am | 96<br>Cm | 97<br>Bk | 98<br>Cf | 99<br>Es | 100<br>Fm | 101<br>Md | 102<br>No | 103<br>Lr |

## La catena protone protone



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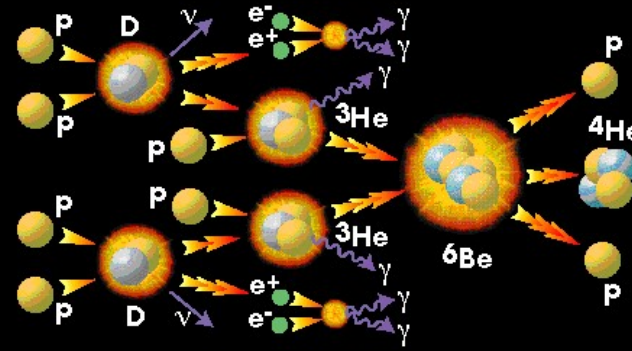
**Abbiamo perso 28 unità di massa =  
0.7 % della massa coinvolta nella reazione**

1000

1000

1000

1000



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3972

Abbiamo perso 28 unità di massa =  
0.7 % della massa coinvolta nella reazione

$$E = m c^2$$

$$E_{\text{reazione}} = 4 \cdot 10^{-12} \text{ J}$$

Numero di atomi di idrogeno:  $10^{57}$

Ogni reazione coinvolge 4 atomi di idrogeno

Ogni reazione produce una energia di :  $4 \cdot 10^{-12} \text{ J}$

Il Sole emette :  $4 \cdot 10^{26} \text{ J} / \text{s} = 4 \cdot 10^{26} \text{ W}$

Ad ogni secondo si verificano :  $10^{38} \text{ reazioni}$

Con questo tasso il sole potrebbe vivere per **70 miliardi di anni**



All'interno della stella avvengono delle reazioni tra le particelle chiamate reazioni nucleari:

