

ΠΡΑΚΤΙΚΑ ΤΗΣ ΑΚΑΔΗΜΙΑΣ ΑΘΗΝΩΝ

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ΑΝΑΚΟΙΝΩΣΕΙΣ ΜΗ ΜΕΛΩΝ

ΜΑΙΕΥΤΙΚΗ.— **The Disadvantages of Radioactive NaCl and the Advantages of Radioactive Na_2Co_3^*** , by *Aristophanes Papaloucas* **. Άνεκοινώθη ὑπὸ τοῦ κ. Σπυρ. Δοντᾶ.

The radioactive ^{24}Na is one of the very first used radioactive isotopes in Medicine. Hamilton and Stone were the first to use it, in 1937, in order to study the excretion of sodium from the body. ^{24}Na is a product of the reaction n, γ (from the stable isotope ^{23}Na), Table I—which takes place in the pile—with a half life of 14,9 hours and 2,76 MeV of γ radiation.

It was previously used in the treatment of leukemia, Hodgkin's disease, sarcoma, polycythemia etc. without any satisfactory effect. During the last years its use was rather bounded in the diagnostic side and experimental investigation.

^{24}Na is an excellent radioactive isotope because: (A) it is a normal constituent of blood and tissues, and therefore it does not give rise to any reactions. (B) It is a short-life-14,9 hours-isotope, so that total body irradiation can be minimized in a short time. (C) It is not selectively absorbed by any organ or tissue in the body. (D) It emits a penetrating γ ray, easily detectable through skin and tissues for external recording.

By the use of radioactive sodium Brown and Veall locate the placenta

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** ΑΡΙΣΤΟΦ. ΧΡ. ΠΑΠΑΛΟΥΚΑΣ, Μειονεκτήματα τοῦ ραδιενεργοῦ χλωριούχου νατρίου καὶ πλεονεκτήματα τοῦ ραδιενεργοῦ ἀνθρακικοῦ νατρίου.

in the intact human uterus, Baron-Veall use it in problems in plastic surgery, Payling Wright in the study of blood circulation. Cox, in the study of the effect of pre-eclamptic toxæmia on the exchange of sodium in the body and the transfer of sodium across the placenta. Lars Werkö and Sam Brody, in the study of the blood pressure in toxæmia of Pregnancy; etc.

The sodium used is brought as sodium chloride, and it is introduced into the pile as NaCl in spite of the disadvantages and risks, which, surely, could be ignored when it is used near the place of its production and in a limited time. But in places or countries far away from the pile, the risks and disadvantages are of importance.

Unfortunately, custom rather than anything else, makes most people use it, probably because it is considered as one of the constituents of blood and tissues, and so not dangerous. Therefore, it was worth considering in order to get a good idea of the disadvantages of radioactive sodium chloride, to explain briefly the various reactions in the pile due to the bombardment of the nucleus of Na and Cl with neutrons.

TABLE I

| <i>Stable Isotopes</i> | <i>Quantity in nature %</i> | <i>Isotopes produced and half-life of them</i> | | |
|-------------------------|-----------------------------|--|------------------------------------|-------------------------------------|
| Reaction | | n,γ | n,p | n,α |
| ${}_{11}^{23}\text{Na}$ | 100 | ${}_{11}^{24}\text{Na}$ 14,9 hours | ${}_{10}^{23}\text{Ne}$ 40 seconds | ${}_{9}^{20}\text{F}$ 12 seconds |
| ${}_{17}^{35}\text{Cl}$ | 75,4 | ${}_{17}^{36}\text{Cl}$ $4,4 \times 10^5$ yrs | ${}_{16}^{35}\text{S}$ 87 days | ${}_{15}^{32}\text{P}$ 14,1 days |
| ${}_{17}^{37}\text{Cl}$ | 24,6 | ${}_{17}^{38}\text{Cl}$ 38 minutes | ${}_{16}^{37}\text{S}$ 5 minutes | ${}_{15}^{34}\text{P}$ 12,4 seconds |

The nucleus of stable isotope ${}_{11}^{23}\text{Na}$ gives birth especially to three radioactive isotopes (Table I and II) produced from the following reactions:

Reaction n,γ ${}_{11}^{24}\text{Na}$ (Half life 14,9 hours)

» n,p ${}_{10}^{23}\text{Ne}$ (» » 40 seconds)

» n,α ${}_{9}^{20}\text{F}$ (» » 12 seconds)

[illegible]

As far as $^{23}_{10}\text{Ne}$ and $^{20}_9\text{F}$ are concerned their quantity and half life are not important.

The nucleus of $^{35}_{17}\text{Cl}$ (quantity in nature 75, 4%) and $^{37}_{17}\text{Cl}$ (quantity in nature 24, 6%) produce in the pile the following isotopes;



Reaction n, γ $^{36}_{17}\text{Cl}$ (Half life $4,4 \times 10^5$ years)

» n, p $^{35}_{16}\text{S}$ (» » 87, days)

» n, α $^{32}_{15}\text{P}$ (14,1 days)



Reaction n, γ $^{38}_{17}\text{Cl}$ (Half life 38 minutes)

» n, p $^{37}_{16}\text{S}$ (» » 5 »)

» n, α $^{34}_{15}\text{P}$ (» » 12,4 seconds)

Evidently, the isotopes produced in the pile from $^{37}_{17}\text{Cl}$ even in quantity and the half life are not important. The isotopes $^{36}_{17}\text{Cl}$ and $^{32}_{15}\text{P}$ produced from $^{35}_{17}\text{Cl}$ are not important either, but on the contrary, the isotope $^{35}_{16}\text{S}$ produced also from the stable isotope $^{35}_{17}\text{Cl}$ is important. According to our experiments in the Isotope Division A. E. R. E., Harwell, it was found that: 500 m. c. of NaCl contain 8 m. c. of $^{35}_{16}\text{S}$, with unknown effects on the suprarenals, kidneys, liver etc. and probably harmful, especially when radioactive NaCl is used in pregnancy (where S in the body is increased) for various investigations.

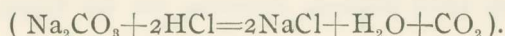
The quantity of $^{35}_{16}\text{S}$ contained in 500 m. c. of NaCl according to time is as follows (Table III).

TABLE III

| Time | Quantity of Radioactive NaCl in m.c. | | Quantity of ^{35}S in m. c. | Containment of ^{35}S in 100 $\mu\text{c.}$ of Radioactive NaCl according to the increased volume of the dilution, because of the half life |
|---------|---|------|--|--|
| 0 Hours | 500 | m.c. | 8 m.c. | 1,6 $\mu\text{c.}$ |
| 15 > | 250 | m.c. | 8 m.c. | 3,2 $\mu\text{c.}$ |
| 30 > | 125 | m.c. | 8 m.c. | 6,4 $\mu\text{c.}$ |
| 45 > | 62,5 | m.c. | 8 m.c. | 12,8 $\mu\text{c.}$ |
| 60 > | 31,25 | m.c. | 8 m.c. | 25,6 $\mu\text{c.}$ |
| 75 > | 15,625 | m.c. | 8 m.c. | 51,2 $\mu\text{c.}$ |
| 90 > | 7,8125 | m.c. | 8 m.c. | 102,4 $\mu\text{c.}$ |
| 105 > | 3,90625 | m.c. | 8 m.c. | 204,8 $\mu\text{c.}$ |
| 120 > | 1,953125 | m.c. | 8 m.c. | 409,6 $\mu\text{c.}$ |

If we take into consideration: 1) The use of the radioactive NaCl for a whole week sometimes. 2) The double or triple quantity of radioactivity, whenever the radioactive material has to be sent to countries far away from the pile and 3) That the administered dose for experimental uses is 100 $\mu\text{c.}$ sometimes, it is obvious that, at the 120th hour after the exit from the pile, dilution considered as containing 100 $\mu\text{c.}$ of radioactive $^{24}_{11}\text{Na}$, contains in addition 409,6 $\mu\text{c.}$ of $^{35}_{16}\text{S}$.

On the other hand by using radioactive Na_2CO_3 we can produce, if we want, NaCl by the addition of HCl, avoiding by this means the harmful effects of radioactive NaCl, as the new mixture contains radioactive sodium but non-radioactive chloride



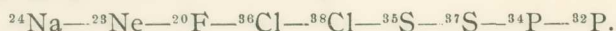
It is advisable to warm slightly the new productions of the chemical reaction in order to evaporate the CO_2 .

Thus as it is proved, from the various reactions which explain the disadvantages of NaCl; Na_2CO_3 has the advantage that the new isotopes produced from it are not able, even by themselves, either in quantity or half life, to cause any harmful effect in the organism. Besides that, we can get rid of them, except sodium, by the above mentioned simple chemical

reaction, after which, we get NaCl (radioactive sodium but non-radioactive chloride).

CONCLUSIONS

1. The pure NaCl at the exit from the pile does not exist any more as NaCl but as a «mixture» containing:



2. The content of ^{35}S is in a considerably large quantity, such as at the 120th hour to be four times greater than ^{24}Na .

3. The use of radioactive Na_2CO_3 is preferable, as we can get, by a simple chemical reaction ($\text{Na}_2\text{CO}_3 + 2\text{HCl} = 2\text{NaCl} + \text{H}_2\text{O} + \text{CO}_2$) NaCl which consists of radioactive ^{24}Na but non-radioactive chloride.

ΠΕΡΙΛΗΨΙΣ

Τὸ ραδιενεργὸν ^{24}Na με χρόνον ὑποδιπλασιασμοῦ 14,9 ὥρων καὶ 2,76 MeV (Μιλλιο-ἡλεκτρονικὰ-βόλτ) ἀκτινοβολίας γ· ἦτο ἐν ἐκ τῶν πρώτων εἰσαχθέντων εἰς τὴν Ἱατρικὴν ἰσοτόπων, παραγόμενον διὰ τῆς ἀντιδράσεως n, γ ἐκ τοῦ ^{23}Na .

Τὸ ^{24}Na πληροῖ τοὺς ἀπαραιτήτους ὅρους ἐνὸς ἀρίστου ραδιενεργοῦ ἰσοτόπου. Τοῦτο εἰσάγεται ἐντὸς τῆς ἀτομικῆς στήλης καὶ βομβαρδίζεται ὡς Χλωριοῦχον νάτριον, χρησιμοποιεῖται δὲ εἴτα θεωρούμενον ὡς ραδιενεργὸν χλωριοῦχον Νάτριον. Παρακολουθοῦντες ὅμως τὰς κατὰ τὸν βομβαρδισμόν τελουμένας πυρηνικὰς ἀντιδράσεις καταλήγομεν εἰς τὸ ὅτι τὸ ἐκ τῆς ἀτομικῆς στήλης ἐξερχόμενον ὡς Χλωριοῦχον Νάτριον δὲν εἶναι ἄλλο τι εἰμὴ μείγμα ραδιενεργῶν στοιχείων, περιέχον $^{24}\text{Na}—^{23}\text{Ne}—^{20}\text{F}—^{36}\text{Cl}—^{38}\text{Cl}—^{35}\text{S}—^{37}\text{S}—^{32}\text{P}—^{34}\text{P}$.

Παρατηρήθη ὅτι πάντα τὰ παραγόμενα ραδιενεργὰ ἰσότοπα στοιχείων πλὴν τοῦ ^{35}S εἶναι ἄνευ σπουδαιότητος, τόσον ὅσον ἀφορᾷ εἰς τὴν ποσότητα, ὅσον καὶ εἰς τὸν χρόνον ὑποδιπλασιασμοῦ. Ἀλλὰ τὸ ^{35}S τόσον κατὰ ποσότητα, ὅσον καὶ κατὰ χρόνον ὑποδιπλασιασμοῦ (87 ἡμερῶν) χρήζει περαιτέρω μελέτης καθ' ὅσον εἶναι πιθανὸν νὰ ἔχη τοῦτο βλαβερὰς συνεπείας ἐπὶ τοῦ ἥπατος, τῶν νεφρῶν καὶ τῶν ἐπινεφριδίων.

Εἰς τὰ ἡμέτερα πειράματα, γενόμενα εἰς τὸ Isotope Division A.E.R.E. Harwell, εὑρέθη ὅτι εἰς ποσότητα Χλωριούχου Νατρίου ραδιενεργείας 500 m.c. (millicurie), περιέχονται 8 m.c. ^{35}S .

Ἐὰν λάβωμεν ὑπ' ὄψιν:

1) Τὴν ὑπὸ πολλῶν χρησιμοποίησιν τοῦ ραδιενεργοῦ χλωριούχου νατρίου πολλάκις ἐπὶ δόλοκληρον ἐβδομάδα, καθ' ἣν τοῦτο ὑποδιπλασιαζόμενον ἐξασθενεῖται.

2) Τοῦ περιεχομένου διπλασίου ἢ τριπλασίου ποσοῦ ραδιενεργείας, προκειμένου περὶ μακρὰν εὐρισκομένων χωρῶν, ὥστε κατὰ τὴν παραλαβὴν νὰ περιέχεται εἰς αὐτὸ ἡ αἰτηθεῖσα ποσότης.

3) ὅτι ἡ διὰ πειραματικὸν σκοποὺς χορηγουμένη δόσις ἀνέρχεται πολλάκις εἰς 100 μ. c. (microcurie), προκύπτει ἐκ τούτων ὅτι τὴν 120ην ὥραν ἀπὸ τῆς ἐξόδου του ἐκ τῆς ἀτομικῆς στήλης, διάλυμα θεωρούμενον ὡς περιέχον 100 μ. c. (microcurie), ^{24}Na , θὰ περιέχῃ καὶ 409,6 μ. c. ^{32}S , ἥτοι τετραπλασίαν καὶ πλέον ποσότητα ^{32}S ἀπὸ τὸ ^{24}Na .

Ἀντιθέτως διὰ τῆς χρήσεως τοῦ ραδιενεργοῦ ἀνθρακικοῦ νατρίου καὶ τῆς ἐξ αὐτοῦ διὰ προσθήκης ὑδροχλωρικοῦ ὀξέος παρασκευῆς χλωριούχου νατρίου ἀποφεύγονται αἱ πιθαναὶ βλαβεραὶ συνέπειαι τοῦ ραδιενεργοῦ χλωριούχου νατρίου, διότι τὸ παραγόμενον μείγμα, τὸ ὁποῖον περιέχει ραδιενεργὸν Νάτριον, ἔχει πρὸς τοῦτοις Χλώριον ἀνενεργὲς ($\text{Na}_2\text{CO}_3 + 2\text{HCl} = 2\text{NaCl} + \text{H}_2\text{O} + \text{CO}_2$).

Ὅθεν τὸ ἀνθρακικὸν Νάτριον δέον νὰ προτιμᾶται πρὸς θεραπευτικὴν χρῆσιν, διότι βομβαρδιζόμενον παράγει νέα ἰσότοπα, ἅτινα δὲν εἶναι ἱκανὰ νὰ προκαλέσουν καθ' οἷονδήποτε τρόπον βλαβεράν τινα παρενέργειαν ἐπὶ τοῦ ὁργανισμοῦ τοῦ πάσχοντος.

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