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AN EXTENSION SET FOR ^{81}Rb-^{81m}Kr SOLUTION GENERATORS FOR LUNG VENTILATION STUDIES

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AN EXTENSION SET FOR 81Rb-81mKr SOLUTION GENERATORS FOR LUNG VENTILATION STUDIES.

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Recently, an increasing number of clinical applications of ^{81m}Kr has been reported involving intravenous administration of the radionuclide dissolved in an isotonic solution. At present, generators of different design are being used: the so-called "gas generators" for ventilation studies and "solution generators". The former are used for elution with air and the latter with isotonic solutions. The actual situation is that solution generators are practically not suited for elution with air, while gas generators cannot be used for elution with solutions. A more efficient and economic use of ^{81}Rb may be achieved when solution generators can be eluted alternately with an isotonic solution for intravenous administration and with air for ventilation studies.

The idea of operating a solution generator with a continuous flow of air appears to conflict with the fulfillment of two basic requirements to the solution generator. First, a continuous flow of air for prolonged times demands humidified air to prevent the generator from running dry, with the risk of deteriorating the sterile state obtained by aseptic preparation. Second, after elution with air the efficiency of elution with an isotonic solution may become substantially lower, possibly due to channel formation. Therefore, we have considered another approach, viz. by operating the solution generator only in the solution mode, thus ensuring its integrity. Gaseous ^{81m}Kr is obtained by stripping the aqueous eluate with a stream of air in a bubble column connected as an extension set to the solution generator. The generator can now be operated alternately in a "perfusion mode" and in a "ventilation mode" and vice versa by simply switching a three-way valve (Fig.1). This study aims at proving the feasibility of this approach based on a prototype and furthermore to get more insight into the parameters of interest for an optimum design of the bubble column and its operating conditions. A theoretical model describing the efficiency of the system, which is mainly limited by aqueous phase diffusion of ^{81m}Kr, was published elsewhere [1].

In Fig.1 the prototype of the bubble-column extension set is presented schematically. The set consists of three concentric perspex cylinders on a bottom plate, with internal diameters of 60 mm, 80 mm, and 200 mm respectively, each with a height of 180 mm. At the top they are sealed with a removable lid. The inner cylinder (1) is the bubble column with an air injection plate (6) at the bottom. The solution feeding pipe (3) with 1 mm internal diameter and 200 mm length, ends 10 mm above the bottom plate. The annular space (9) between the middle and outer cylinder serves as waste collection vessel. The annular space between the inner and middle cylinder contains a 3 mm thick lead shielding (2). Inside the bubble column a draught pipe (2) is inserted, consisting of a thin-walled (1 mm thick) perspex cylindrical wall with an inner diameter of 50 mm and a height of 110 mm. The draught pipe ends 10 mm above the waste discharge pipe (10) and 10 mm below the spray trap (7,8). The lower end of the draught pipe is provided with circular holes (5 mm diameter). Insertion of this draught pipe results in a more regular bubbling pattern and higher gas hold-up enabling an improvement of the stripping efficiency. Since water can always flow over the edge of the top of the draught pipe into the annular space, flooding of the bubble column (resulting in water entrainment by air) is suppressed in this way.

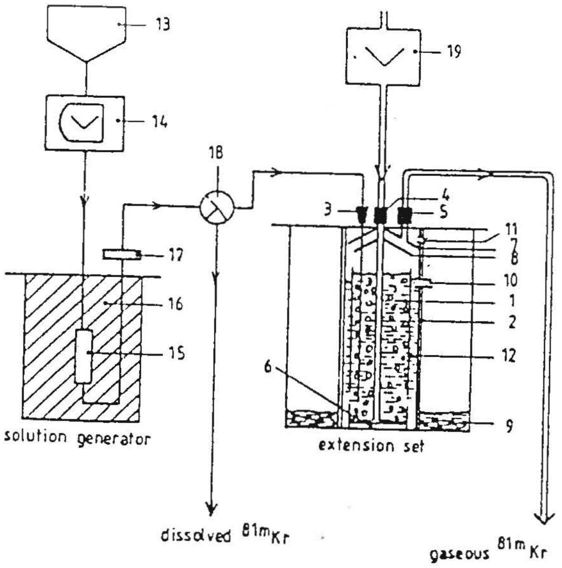

Figure 1. Schematic presentation of the combination of solution generator and extension set ; (1) bubble column ; (2) lead shielding; (3) solution feeding pipe ; (4) and (5) air in/out tubes, 4 mm ID ; (6) bubble injection plate, with 32 orifices of 0.3 mm , (7) and (8) spray trap; (9) solution waste collection; (10) solution discharge pipe from bubble column to waste; (11) channel for pressure discharge of waste compartment; (12) draught tube, 50 mm ID; (13) sterile 5% glucose solution bag; (14) peristaltic pump for glucose solution ; (15) solution generator ion exchange column; (16) lead shielding; (17) sterile filter; (18) sterilised three-way valve, connected to sterilised 0.8 mm ID polyethylene tubing conveying solution; (19) air pump, operated at 2-4 L min^{-1}.

Measured and theoretical overall yields are presented in Fig. 2; the separate points denote the experimental values, while the solid curves refer to the theoretical values. Both experimental and theoretical data involve the following conditions: air flow rates between 0.5 and 4 L min^{-1} in the presence as well as in the absence of the draught pipe. A bubble injection plate with 0.3 mm orifices was used. The curves III and IV involve a temperature of 20 °C, while curve V (with associated points) involves a temperature of 50 °C. At flow rates corresponding to superficial gas velocities (i.e. the ratio of flow rate to cross section area) higher than ca .022 m s^{-1}, water entrainment and coalescence of bubbles tend to occur.

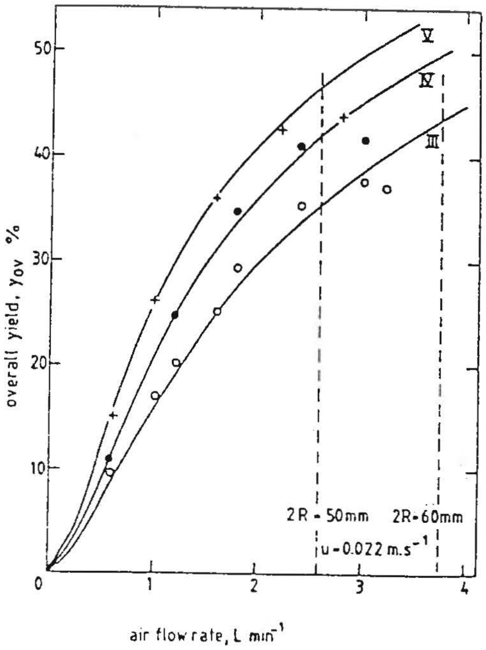

Figure 2. Measured overall ^{81m}Kr recovery yields from the combination of the solution generator and the extension set as a function of the applied air flow rate. 0: 60 mm internal column diameter, 0: 50 mm internal column diameter, + : 50 mm internal column diameter at a solution temperature of 50 °C. The solid curves III, IV, and V were calculated. Air flow rates corresponding to a superficial gas velocity of 0.022 m s^{-1} are indicated for the 60 mm and the 50 mm column diameters.

The maximum overall yield obtained for a temperature of 20 °C of the solution in the bubble column amounts to ca 41% at an air flow rate of 2.5 L min^{-1}, using a column diameter of 50 mm (draught pipe inserted) and a bubble injection plate with orifice diameter of 0.3 mm. According to the theoretical model, at these conditions the relative losses in the separate compartments are as follows: 15% in the solution generator, 8.0% in the connecting tubing due to decay, 39% in the bubble column due to incomplete stripping, 0.8% due to spill-over, and 14% in the gas phase of the bubble column due to decay. Thus, the main factor reducing the overall yield is the low stripping efficiency (61%). The stripping efficiency is limited by the transfer via diffusion of ^{81m}Kr dissolved in water to the gas phase. This process, being relatively slow, causes substantial decay of ^{81m}Kr in the water phase. The most effective way of improving the overall yield must be sought in increasing the available interfacial surface area by increasing the volumetric gas fraction or decreasing the bubble diameter (for instance by stirring), or by increasing the diffusion rate by operating the extension set above room temperature.

With the combination of a ^{81}Rb/^{81m}Kr solution generator and the prototype of the extension set for production of gaseous 81mKr, an overall yield of ca 41% may be achieved, provided (i) minimum volumes are used for the connecting tubing to the feeding solution generator, (ii) the inner diameter of the bubble column is matched with the desired air flow rate to obtain a superficial air velocity close to 0.02 m s^{-1}, and (iii) adequate bubble injection orifices are applied. Furthermore, improvement of the overall yield to at least 60% appears feasible by an increase of the temperature of the aqueous phase in the bubble column and particularly by stirring, possibly in combination with addition of electrolytes. When using the extension set in combination with a 740 MBq (20 mCi) solution generator, an equivalent of a ventilation generator output of 305 MBq (8.2 mCi) is achievable. Since the yield of ventilation generators is usually between 90 and 95%, this output corresponds to a nominal ventilation generator strength of 320 to 340 MBq (8.6-9.1 mCi). This compares well with the activity range of 220-440 MBq (6-12 mCi) of the usual ventilation generators. Thus, the simple extension set may be a useful and inexpensive enlargement of the clinical possibilities, viz.for measurement of ventilation/perfusion ratios with only a single generator system.

1. Janssen, A.G.M., Witsenboer, A.J., and De Goeij, J.J.M., Appl.Radiat.Isot., 39, 87 (1988)