Canadian Nuclear Society

Nu-Salt or NoSalt as a radioactive source fact sheet

www.cns-snc.ca/ecc/cnsecc.html

$^{40}_{19}K$ &

Nu-Salt® or NoSalt®

Potassium-40 (^{40}K) is a naturally occurring radioactive isotope of the common element potassium (potassium represents about 2.4% by weight of the earth's crust). The half-life of ^{40}K is 1.248 x 10^9 years [1] — its origins are primordial. ^{40}K has an atomic percent abundance of 0.0117%. (^{39}K is 93.1% and ^{41}K is 6.88%, both are stable.)

$^{40}K \xrightarrow{89\%} {}^{40}Ca + \beta^- + \bar{\nu}$ E = 1.311 MeV

$^{40}K + e^- \xrightarrow{11\%} {}^{40}Ar + \nu$ E = 1.505 MeV

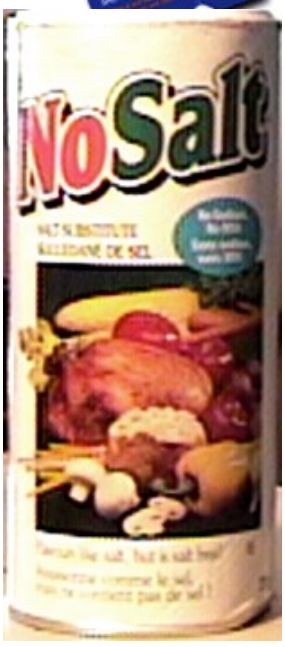
γ = 1.46 MeV

(Both ^{40}Ca and ^{40}Ar are stable)
(either electron capture or β^+ decay (0.001%) produce ^{40}Ar with γ; β^+ annihilates when it interacts with an e^- leading to γ of 0.511 MeV)

The beta particles of the maximum energy have a range in water of about 1 cm. These interact with atoms to produce lower energy beta particles and low-energy gamma rays. The anti-neutrino and neutrinos carry a fraction of the energy. The electron capture results in the orbital electrons having an X-ray cascade with energies up to the maximum.

The ^{40}Ar / ^{40}K ratio in materials (that trap argon) may be used for geological dating.

While potassium is a very common element, one does not usually find it in a concentrated form (except as potash in fertilizers). *Nu-Salt*® and *NoSalt*® are dietary substitutes for common table salt, sodium chloride. Doctors recommend these products for *some* patients to reduce their sodium intake. (Note: potassium chloride is administered intravenously in some medical procedures to affect heart rate, and a *concentrated* solution is used for *execution by lethal injection* in some jurisdictions.)



The FAQ page for *Nu-Salt*® has the following information [2]:

1. **What are the ingredients in *Nu-Salt*®?**
   Nu-Salt contains potassium chloride, potassium bitartrate, calcium silicate and natural flavor derived from citrus fruits and honey.

2. **What is the function of each ingredient?**
   Potassium chloride = is the salt substitute component of the blend.
   Potassium bitartrate = flavor modifier.
   Calcium silicate = anticaking agent.
   Natural flavor = taste modifier.

3. **How much potassium does *Nu-Salt*® contain?**
   Nu-Salt contains 0.528 grams or 528 milligrams of potassium per 1/8-teaspoon serving.

4. **Why does *Nu-Salt*® have such a high potassium content?**
   The minimum potassium requirement for adults is approximately 1600 to 2000 milligrams per day. The potassium content of Nu-Salt is 530 milligrams per 1/6 tsp. (1 g) serving which is approximately the same as the amount of potassium in one medium banana or one cup of fresh cantaloupe. Potassium chloride is used as a substitute for the common salt, sodium chloride.

5. **Is *Nu-Salt*® kosher?**
   Yes. Nu-Salt is considered kosher by the Union of Orthodox Rabbis. Nu-Salt is parve.

6. **How is *Nu-Salt*® sold and where can I buy it?**
   Nu-Salt is available in 2.5 ounce canisters and boxes of 50 packets. It is available in the baking aisle of supermarkets, drugstores, wholesale clubs and discount chains.

7. **What is the suggested retail price of *Nu-Salt*®?**
   Nu-Salt has a suggested retail price of $1.09 to $1.39 for the 2.5 ounce canister and $1.29 to $1.49 for the 50-packet boxes.

Analysis

The *Nu-Salt* FAQ states that a (*large?*) banana has about 528 mg of potassium. The following table provides a list the potassium content of selected foods with the estimated activity (about 0.032 Bq per mg potassium).

Potassium Content and Potassium-40 Activity in Some Selected Foods				
Food	Portion	Potassium [mg]	K-40 [µg]	Activity [Bq]
Hot Dog	1 plain @ 98 g	143	16.7	4.5
Double Hamburger	1 loaded @ 226 g	570	66.7	18.1
Chicken, roasted	¼ @ 195 g (light & dark)	447	52.3	14.2
French Fries (veg. oil)	10 strips @ 50 g	306	35.8	9.7
Broccoli (raw)	3 spears @ 93 g	302	35.3	9.6
Brewed Coffee (black)	250 mL @ 250 g	135	15.8	4.3
Banana	1 medium @ 150 g	454	53.1	14.4
Orange juice, chilled	250 mL @ 263 g	500	58.5	15.9
2% Milk	250 mL @ 258 g	398	46.6	12.6
Skim Milk	250 mL @ 259 g	429	50.2	13.6
Figs, dried, uncooked	10 @ 137 g	1331	155.7	42.2
Potato, baked, skin on	1 @ 202 g	844	98.7	26.8
Bran Flakes, Post™	175 mL @ 37 g	177	20.6	5.6
Maple syrup	15 mL @ 20 g	41	4.8	1.3
Whole Wheat Bread	1 slice @ 28 g	71	8.3	2.3
White Bread	1 slice @ 25 g	30	4.0	1.0
Sunflower Seeds, dried	75 mL @ 41 g	345	40.4	10.9
Peanut Butter	30 mL @ 32 g	234	27.4	7.4
Egg	1 large @ 33 g	47	5.0	1.5

Source: Potassium concentrations from Health Canada, "Nutrient Value of Some Common Foods" http://www.hc-sc.gc.ca/fn-an/alt_formats/hpfb-dgpsa/pdf/nutrition/nvscf-vnqau_e.pdf

The 2.5 ounce *Nu-Salt*® canister has about 71 g of KCl. Approximately 34.7 g of the salt is potassium, or 0.96 gram-mole. The Nu-Salt canister is equivalent to about 66 "large" bananas and each banana is therefore a source of about 17 Bq (compared to 14 Bq in the table above).

The *Nu-Salt* canister has about 5.73×10^{23} potassium atoms, of which 6.7×10^{19} are ^{40}K. In 1.25×10^{9} years, half of these will have decayed, so at the present time, *on average* 1179 of the ^{40}K atoms in the container will decay in each second. This represents a radioactive source of 1.18 kBq.

The larger 311 g *NoSalt*® container has about 2.8×10^{20} ^{40}K atoms, of which 4927 decay per second (*on average*) for an activity 4.93 kBq.

A 70 kg person contains about 140 g of potassium [3] — or about 4 containers worth of the potassium in a 2.5 ounce *Nu-Salt* canister — or about 90% of the amount in the *NoSalt* container. This represents a source of about 4.44 kBq. ^{40}K is the dominant radionuclide in the human body, and delivers a dose of about 0.2 mSv per year [4]. The reference daily intake for potassium by an adult is 4.7 g [5] (149 Bq). (A 75 kg male is a source of about 8 kBq [6].)

Nu-Salt® and *NoSalt*® are convenient radioactive sources for the classroom. You may purchase them in the spice section of a grocery store or at a pharmacy. See Appendix: Licensing of Radioactive Sources in Canada.

Nu-Salt® is a registered trademark of Cumberland Packing Corp., Brooklyn, New York 11205.
NoSalt® is a registered trademark of Joh. A. Benckiser, GmbH.

Another common source of concentrated potassium is chemical fertilizers. In this case the potassium is in the form of "soluble potash", K_2O. Lawn fertilizers such as 7-7-7 contain 7% by weight of soluble potash [7]. (Total nitrogen, the first number of the three is also 7% and does not include the other elements present in the nitrogen containing molecules.) Such fertilizer is a much weaker source of ^{40}K than potassium chloride at 18 kBq in a 10 kg bag of 7-7-7, or 1.8 Bq/g compared to ~17 Bq/g.

References:

[1] Interactive Chart of the Nuclides, www.nndc.bnl.gov/chart/

[2] Nu-Salt web page, www.nusalt.com

[3] Ed Uthman, M.D., "Elemental Composition of the Human Body," www.neosoft.com/~uthman/elements)of_body.html

[4] Noel Giffin, "Natural Radioactivity in the Human Body," http://www.triumf.ca/safety/rpt/rpt_4/node7.html

[5] http://www.hc-sc.gc.ca/fn-an/nutrition/reference/table/ref_elements_tbl_e.html

[6] http://www.npp.hu/mukodes/aktivitas-e.htm

[7] http://laws.justice.gc.ca/en/f-10/c.r.c.-c.666/241104.html

Suggestions for experiments:

1. How much mass area-density is required to reduce the excess count rate relative to background by half?

   (Hint: use thin sheets of low-Z materials such as paper or aluminum foil).

2. Using a known mass of KCl, measure the excess count rate. Calculate the radioactivity of this sample. Estimate the efficiency of your detector arrangement.

   (Hint: neglecting back-scattering from the table, normalize your counts by dividing by the ratio of the area of your detector window to the area of a sphere having a radius equal to the source-detector distance.)

   - What arrangement maximizes the efficiency?

Example Procedure & Results:

To support the *Aware*® detector above the sample, use a shallow plastic cup of about the same diameter. For an RM-80, the plastic container from muffin cups is a convenient size.

1. Place a small amount of table salt (NaCl) — say ¼ teaspoon (1.25 mL). You may need a plastic bottle cap or other holder to make the diameter of the salt pile about the same as that of the detector window.

2. Determine the background count rate.

3. Replace the table salt with the same amount of KCl.

4. Determine the count rate.

5. Cut circles of thin aluminum foil to match the inside diameter of the support container.

6. Add the sheets of aluminum foil one at a time, and determine the count rates (at least 8).

7. Check the background count rate again when you are done.

8. Plot the count rate excess above background as a function of the number of foil disks.

   Note that this is a mixed-radiation field measurement. Both energetic electrons and gamma ray photons are detected. The energetic electrons are stopped in a small amount of aluminum. Gamma rays are less easily attenuated. You may see the count rate increase after the first minimum. Possible explanations include scattering of gamma rays generating a "dose build-up" of low energy electrons that interact with the counter more effectively than the gamma, or other scattering effects.

   Such graphs usually shows “uncertainty bars”. What determines how large they should be?

Appendix Licensing of Radioactive Sources in Canada

The Canadian Nuclear Safety Commission (formerly the Atomic Energy Control Board) is the agency of the Government of Canada that is responsible for regulating the safe use of radioactive sources.

The Nuclear Substances and Radiation Devices Regulations, *Canada Gazette Part II, Vol. 134, No. 13*, 2000-06-21 (www.nuclearsafety.gc.ca/pubs_catalogue/uploads/Sor207.pdf) Section 1 stipulates that the exemption quantity for licensing a radioactive source not listed in “Schedule 1” for substances having an atomic number of less than 81 is 10 kBq.

Note that ^{42}K is listed in the Schedule (page 21 of the document) where 10^4 Bq is also cited. ^{42}K also undergoes beta-decay and has a half-life of only 12.4 h.

Approximately 602 g of KCl would correspond to the 10 kBq exemption limit for licensing.

> Hence, for use as a radioactive source, one may possess a maximum of two *NoSalt*® containers (622 g) without having obtained a license from the CNSC.

The supply and consumption of KCl as a dietary alternative to NaCl is the subject of Health Canada regulations. The grocery stores, pharmacies, and consumers are not subject to the CNSC regulations as their possession of the material is not for use as a source of ionizing radiation.