ORNL/TM-2023/3052

Optimal Chloride Salt Mixture for a Fusion Blanket

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September 2023

OAK RIDGE National Laboratory

ORNL IS MANAGED BY UT-BATTELLE LLC FOR THE US DEPARTMENT OF ENERGY

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Nuclear Energy and Fuel Cycle Division

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ABBREVIATIONS

CALPHAD	Calculation of Phase Diagrams
DOE	US Department of Energy
D-T	deuterium-tritium
FASTR	Facility to Alleviate Salt Technology Risks
FERMI	Fusion Energy Reactor Models Integrator
FLiBe	$(LiF)_2$ and BeF_2
FOM	figure of merit
LSTL	Liquid Salt Test Loop
MHD	magnetohydrodynamic
MSTDB-TC	Molten Salt Thermal Properties Database–Thermochemical
MSTDB-TP	Molten Salt Thermal Properties Database–Thermophysical
NAS	National Academies of Sciences
ORNL	Oak Ridge National Laboratory
PbLi	a metallic eutectic of lead and lithium
PWR	pressurized water reactor
RK	Redlich–Kister
SNS	Spallation Neutron Source
TBR	tritium breeding ratio
TC	thermochemical
TP	thermophysical

EXECUTIVE SUMMARY

Deuterium-tritium fusion reactors cannot operate for a significant period without a closed tritium fuel cycle, according to a recent National Academies of Sciences (NAS) report on bringing fusion reactors to the US electrical grid [1]. This fact places breeder blankets as one of the foundational systems for self-sustained fusion reactor operation. The typical functional requirements for a breeder blanket system include producing tritium, absorbing kinetic energy, transporting thermal energy, and being environmentally attractive.

State-of-the-art research on liquid blankets has converged to primarily focus on $(LiF)_2$ and BeF_2 (FLiBe) molten salts and a metallic eutectic of lead and lithium (PbLi), but "virtually all of the technologies related to the tritium fuel cycle are at a low technological readiness level" [1]. This work sought to explore optimum blanket configurations as it aligned with the Oak Ridge National Laboratory (ORNL) FY 2023 Laboratory Directed Research and Development Program's research priority of developing and expanding the current understanding of fusion blanket science and technology.

This purpose of this work was to address ORNL research priorities and NAS recommendations by investigating novel liquid blanket materials that could provide self-sustaining operation and draw on experience from research on molten salts used for advanced fission reactors [2], concentrated solar [3], and thermal energy storage [4]. The hypothesis when proposing this research was that there could be chloride-based blanket designs that can exceed the tritium breeding ratios of (FLiBe) molten salt blankets while reducing the use of Be (FLiBe), avoiding the generation of HF (FLiBe), and minimizing magnetohydrodynamic (MHD)-perturbed flow fields (PbLi). The fastest and most cost-effective path to deploying liquid fusion breeder blankets could be from maximizing the synergistic technological overlap between fusion, fission, concentrated solar, and thermal energy storage industries (see Figure 1).

The goal of this research was to systematically identify chloride-based salts with desirable economic, neutronic, thermophysical, and thermochemical properties for use as a liquid fusion breeder blanket and then compare such plausible salts with state-of-the-art FLiBe molten salt. If proven to yield sufficient tritium production, a chloride salt blanket could avoid the primary disadvantages of FLiBe (presence of Be toxicity and generation of HF) and PbLi (MHD forces affecting fluid flow and heat removal).

After using such properties as filters to reduce to domain size, low-, medium-, and high-cost neutronic simulations were performed to quantify tritium production on both simplified and realistic fusion reactor geometries. The top performing chloride salts were compared with FLiBe as the benchmark. Over 30 binary and 20 ternary compositions were identified with superior tritium production. Although tritium production is the highest-priority metric, a balance must also be achieved with other economic, thermophysical, and thermochemical parameters. Table 10 presents a scoring and ranking of the most promising binary salts using tritium production, liquidus temperature, price, toxicity, ionic states, redox potential, activation potential, fluid flow, and heat transfer metrics.

A weight was subjectively assigned to each category. The highest-scoring salt neglecting fluid and heat transfer figures of merit (FOMs) was LiCl-NaCl, followed closely by LiCl-$PbCl_2$, LiCl-$MgCl_2$, and LiCl-$SrCl_2$. When considering the additional FOMs, LiCl-NaCl remains at the top, LiCl-$PbCl_2$ does not get evaluated owing to a lack of data, and LiCl-$MgCl_2$ extends its lead on LiCl-$SrCl_2$ with more favorable flow and heat transfer scores. Appendix D presents the performance and data availability of the most promising binary salts, sorted by tritium production in descending order evaluated at 873 K [600°C].

Data needs and future work discussions can be found in Sections 4.3 and 4.4. A Git repository is also available [5].

Highlights of chloride salt performance relative to FLiBe include the following:

1. Several compositions were found with higher-than-FLiBe tritium production potential.
2. Higher-than-FLiBe tritium production was achieved without optimizing blanket dimensions for chloride salts.
3. The liquidus temperature distribution of chlorides with more tritium production than FLiBe ranges ±100°C around that of FLiBe. Ternary chloride salts have a 30°C lower average liquidus temperature than the binary chloride salts.
4. Commercial-scale pricing is difficult to estimate. Recent small-batch FLiBe salt procurements at ORNL have cost between $1,000 to $2,000/kg. Given the $1,000/kg filter used in this study, all prospective chlorides are less expensive and driven by the 80%–90% LiCl mass fraction at ≈$360/kg.
5. Chloride salts have been identified with higher-than-FLiBe tritium production without Be or Pb.
6. Some chloride salts can exist in multiple ionization states, which complicates blanket chemistry.
7. Activation results suggest that chloride salts have larger decay heat values than FLiBe.
8. FOMs for fluid flow and heat transfer define chloride salts as less desirable than FLiBe primarily because of lower specific heat capacities.
9. An important technology overlap exists with $MgCl_2$ and $CaCl_2$, as they are already used in the halide slagging step of the pyrometallurgical process. Also, the binary salt LiCl-KCl is used in the electrorefining step of the pyrometallurgical process, so significant operational experience and thermophysical and thermochemical properties exist.

Section 3.8 provides a detailed discussion on candidate binary and ternary salt selection. The most promising binary chloride salts were LiCl-$PbCl_2$, LiCl-$SrCl_2$, LiCl-$MnCl_2$, LiCl-$BeCl_2$, LiCl-$CoCl_2$, LiCl-$MgCl_2$, LiCl-NaCl, LiCl-$CaCl_2$, and LiCl-KCl. Based on these binary configurations, the following mass fraction recommendations can be made:

- 0.9LiCl-0.1NaCl at 90% Li is needed to maximize tritium production for Na-containing salts.
- 0.3LiCl-0.7$PbCl_2$ maximizes tritium production, but 0.4LiCl-0.6$PbCl_2$ does nearly as well with a 30°C lower liquidus temperature.
- 0.9LiCl-0.1$MgCl_2$ maximizes tritium production, but 0.8LiCl-0.2$MgCl_2$ may be attractive, with a 50°C lower liquidus temperature.
- 0.8LiCl-0.2$SrCl_2$ maximizes tritium production, but 0.7LiCl-0.3$PbCl_2$ does nearly as well with a 32°C lower liquidus temperature.
- 0.5LiCl-0.1$MgCl_2$-0.4$PbCl_2$ produced the most tritium of any ternary salt and had one of the lowest liquidus temperatures at 678 K [405°C].
- 0.7LiCl-0.2$MnCl_2$-0.1$SrCl_2$ and 0.6LiCl-0.2$MnCl_2$-0.2$SrCl_2$ performed near the top of the ternary salts without the use of $PbCl_2$.
- 0.8LiCl-0.1$MgCl_2$-0.1NaCl was the highest tritium-producing salt containing both NaCl and $MgCl_2$.

1. INTRODUCTION

1.1 BRIEF BACKGROUND OF FUSION BREEDER BLANKETS

Deuterium-tritium (D-T) fusion reactors cannot operate for a significant period of time without a closed tritium fuel cycle, according to a recent National Academies of Sciences (NAS) report on bringing fusion reactors to the US electrical grid [1]. This fact places breeder blankets as one of the foundational systems for self-sustained fusion reactor operation. The typical functional requirements for a breeder blanket system include producing tritium, absorbing kinetic energy, transporting thermal energy, and being environmentally attractive. Conceptual designs of liquid, solid, and combination blankets have been developed in the past.

State-of-the-art research on liquid blankets has converged to primarily focus on $(LiF)_2$ and BeF_2 (FLiBe) molten salts and a metallic eutectic of lead and lithium (PbLi), but "virtually all of the technologies related to the tritium fuel cycle are at a low technological readiness level" [1]. This work sought to explore optimum blanket configurations as it aligned with the Oak Ridge National Laboratory (ORNL) FY 2023 Laboratory Directed Research and Development Program's research priority of developing and expanding the current understanding of fusion blanket science and technology. This work directly addressed ORNL research priorities and NAS recommendations by investigating novel liquid blanket materials that could provide self-sustaining operation and draw on experience from research on molten salts used with advanced fission reactors, concentrated solar, and thermal energy storage. This work focused on liquid blanket materials that reduced the use of Be (FLiBe), avoided the generation of HF ($(LiF)_2$ and BeF_2 (FLiBe)), and minimized magnetohydrodynamic (MHD)-perturbed flow fields (PbLi). Chloride-based salts avoided these negative characteristics and their development; a fusion breeder blanket could leverage substantial research in chloride salt systems in the fission, concentrated solar, and thermal energy storage industries.

FLiBe salt research benefits both fusion and fission fields because of technology overlaps. However, Be has strict handling requirements because of unique health hazards. Liquid metal blankets such as PbLi eutectics are affected by MHD forces, which must be accounted for. Chloride-based salts avoid these negative characteristics while retaining desirable high-temperature properties. Chloride-based salt blanket development could leverage substantial research in chloride salt systems such as fission, concentrated solar, and thermal energy storage (see Figure 1). For these reasons, chloride-based salts should be investigated as a potential liquid breeder blanket for fusion applications.

Despite its potential as a liquid breeder, very little literature published before 2008 could be identified assessing the feasibility of chloride-based salt fusion blankets [6]. Pre-2008 research findings consisted of recommendations that chloride salts would require thicker blankets than fluoride salts and found that chloride salts, with an inherently higher neutron energy spectrum, appreciate a ^{238}U multiplying layer before the blanket [7]. However, the recent surge in fusion research has led to at least two publications in the 2020s related to chloride salt fusion breeder blankets [8; 9]. These efforts highlight the many advantages and disadvantages of chloride salts relative to the state of the art, suggest a few chloride salt compositions, and present findings that suggest tritium breeding ratios equal to FLiBe but below PbLi are achievable with chloride-based liquid blankets.

1.2 RESEARCH PURPOSE

This purpose of this work was to directly address ORNL research priorities and NAS recommendations by investigating novel liquid blanket materials that could provide self-sustaining operation and draw on experience from research on molten salts used with advanced fission reactors [2], concentrated solar [3], and

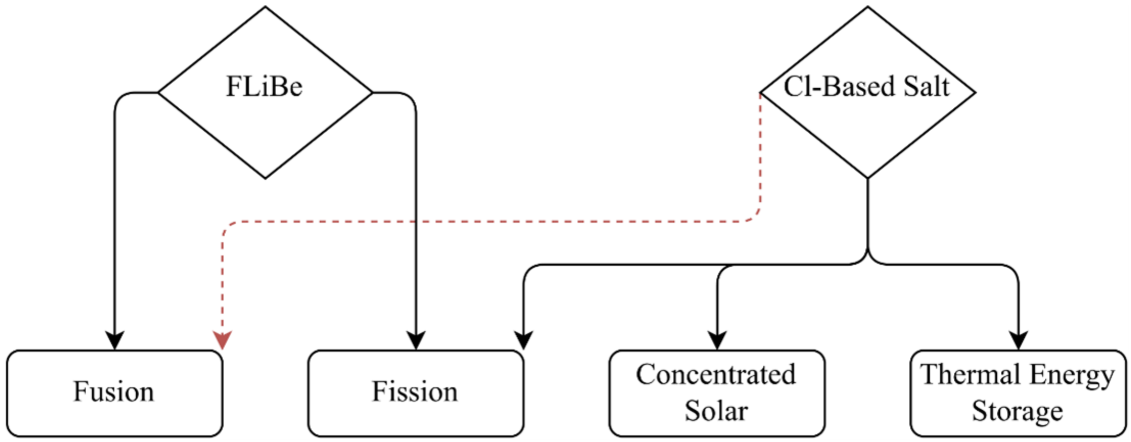


Figure 1. Technology overlap that could help the fusion industry derisk the molten salt breeder blanket pathway.

thermal energy storage [4]. The hypothesis when proposing this research was that there could be chloride-based blanket designs that can nearly equal or exceed the tritium breeding ratios of FLiBe molten salt blankets. The fastest and most cost-effective path to deploying liquid fusion breeder blankets could be from maximizing the synergistic technological overlap between fusion, fission, concentrated solar, and thermal energy storage industries.

The goal of this research was to systematically identify chloride-based salts with desirable economic, neutronic, thermophysical (TP), and thermochemical (TC) properties for use as a liquid fusion breeder blanket and then compare such plausible salts with state-of-the-art FLiBe molten salt. If proven to yield sufficient tritium production, a chloride salt blanket could avoid the primary disadvantages of FLiBe (presence of Be toxicity and generation of HF) and PbLi (MHD forces affecting fluid flow and heat removal).

2. APPROACH

The determination of optimal chloride salts begins with a complete or near-complete list of possible salts. In this report, a unary salt refers to the combination of two elements into a single chloride molecule (e.g., LiCl), a binary salt refers to the combination of two chloride molecules (e.g., LiCl-NaCl), and a ternary salt refers to the combination of three chloride molecules (e.g., LiCl-NaCl-KCl). Quaternary salt refers to the combination of four chloride molecules.

The unary list was first populated with salts from Janz et al. [10] and expanded by searching chemical vendor inventories. The compilation of these resources led to the identification of 79 plausible unary chloride salts. Plausible binary, ternary, and quaternary salts were generated using the combinations function within the Python itertools module. At this point, the lengths of the plausible binary, ternary, and quaternary lists were 3,081, 79,079, and 1,502,501 salt combinations long, respectively. Notably, the additional dimensions of varying the weight fractions and isotopic enrichment had not yet been implemented for each salt.

The salt lists were further expanded to include a range of weight fractions between 10% and 90% with a 10% step size for each molecule of the binary salts, as well as a range of 10% to 80% for each molecule of the ternary salts. The inclusion of this dimension generated 9 compositions for each binary salt and 36 compositions for each ternary salt.

With the goal to quantify the breeder blanket tritium production across a very large set of salts with as little bias as possible, a multilevel serial filtering process was applied. This set of filters was loosely designed to minimize computational cost. This systematic downselection of the most promising chloride-based salts focuses on economic, neutronic, TP, and TC parameters to optimize.

After the data-driven filtering process had been completed, the most promising chloride salts were investigated using transport and depletion sequences within the SCALE [11] suite of products. Finally, from this data set, the best-performing chloride salts were identified and compared with FLiBe, the benchmark molten salt breeder blanket material.

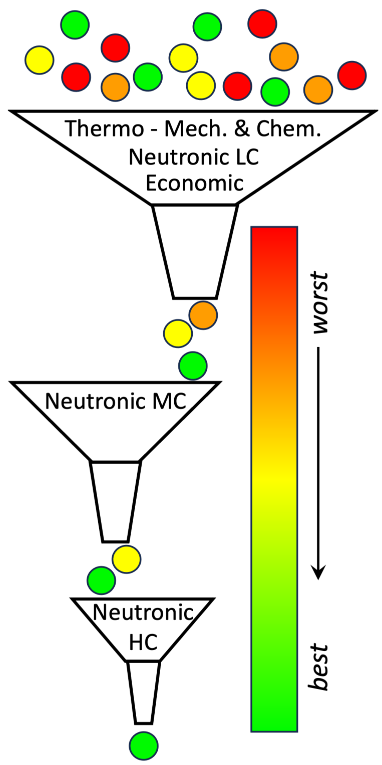


Figure 2. Multilevel serial filtering process used to determine optimal chloride salts for use as a fusion breeder blanket. Neutronic filters are abbreviated for low-cost (LC), medium-cost (MC), and high-cost (HC).

2.1 ECONOMIC FILTERS

Economic filters were employed first because of their low relative computational cost. The first economic filter of the process was a Boolean check on the commercial availability of a given unary chloride salt by confirming inventory at major chemical suppliers such as Sigma-Aldrich, Avantor/VWR, Alfa, and others.

If commercially available, the unit price ($/kg) was appended to the price array found in Appendix A. This price array was then used as a low-pass filter based on a threshold of less than $1,000/kg. Quotes for some salts were requested at both the lab scale (1 to 10 kg) and commercial scale (100,000 kg) to better estimate and extrapolate the pricing.

The $1,000/kg price threshold was selected to qualitatively eliminate low-abundance elements. It also ensured that the fluid cost of the liquid blanket system was maintained below 10% and 1% of the current estimated costs of completing the ARC and ITER fusion reactors [12]. This estimate, of course, does not consider the dynamic nature of markets, government subsidies, or any other possibilities that some material costs may be dramatically reduced (or increased) in the future.

2.2 THERMOPHYSICAL FILTERS

The TP filters of interest included the density, viscosity, thermal conductivity, and specific heat capacity. The primary source of data for these variables was the Molten Salt Thermal Properties Database–Thermophysical (MSTDB-TP) v2.1.1 [13]. This database is under current development by ORNL, and its goal is to be a comprehensive TP properties database for molten salt systems. The database consists of (1) a compilation of previous molten salt property measurements, (2) estimation of property values using first-principles calculations at small atom-scale systems through density functional theory and other molecular dynamics simulations, and (3) interpolation/extrapolation methods through Redlich–Kister (RK) expansion and Muggianu interpolation. The database contains a collection of empirical models that are functions of the temperature and composition.

Both an application programming interface, SALINE [14], and a graphical user interface were developed to interact with the MSTDB-TP. In this effort, SALINE was used to automate the retrieval of as many TP properties as possible. Properties for each salt composition were compiled into a single PANDAS dataframe that could be sorted and filtered accordingly [15].

The MSTDB-TP currently contains 33 pure salt compounds. Of these, 17 are pure chloride compounds. TP properties were retrieved using the additive empirical models based on the mechanical mixture of the pure salt compound constituents [16]. Some psuedobinary composition densities were evaluated using RK interaction parameters to better approximate salt densities relative to the ideal mixing behavior. At this time, RK interaction parameters are not available for ternary chloride salts.

In some instances, density values were not available via the MSTDB-TP database. Therefore, several other sources were consulted to continue the compilation of TP properties, including the Molten Salt Thermal Properties Database–Thermochemical (MSTDB-TC) v2.0 and FTsalt databases queried using FactSage as the interpreter and the Equilib calculation module. FactSage is a fully integrated database computing system for chemical thermodynamics [17].

It was found that MSTDB-TC did not contain the required volumetric information to estimate salt densities. However, FTsalt did contain some volumetric information. A verification effort was made to compare estimated densities from FTsalt with values from MSTDB-TP. Some density comparisons between the two sources were in good agreement, but not all were. This reduced confidence in the FTsalt database output. Therefore, the FTsalt-produced density values were discarded, and the ideal mixing assumption [18; 19] was applied to generate density data for some binary and all ternary salt compositions. In Equation 1, the mixture density, ρ_{mix}, in the RK model is expressed as the sum of the ideal, ρ_{ideal}, and excess, ρ_{ex}, behaviors. Making the ideal mixing assumption allows for neglecting the excess behavior.

$$\rho_{mix} = \rho_{ideal} + \rho_{ex} \approx \rho_{ideal}(1)$$

Therefore, the mixture density can be approximated by the ratio of the sum of molecular mass for unary molecules, $MM_{molecule}$, to the liquid molar volume in Equation 2:

$$\rho_{mix} \approx \rho_{ideal} = \frac{\Sigma x_i \cdot MM_{molecule,i}}{\Sigma \frac{x_i \cdot MM_{molecule,i}}{\rho_i}}, \tag{2}$$

where ρ_i is the density for a unary molecule. For the NaCl-KCl salt system, the relative difference between the ideal density and either the experimental measurements or RK interpolation is less than 5% [19]. Notably, this relative difference was still bounded by the uncertainty of the experimental measurement for NaCl-KCl density. Therefore, the ideal mixing approximation appears to be sufficient for this effort. The number of salts requiring this density approximation highlights the significant need for more experimental measurement of chloride salts.

Values of viscosity, thermal conductivity, and specific heat capacity were only retrieved from the MSTDB-TP. A lower priority was placed on compiling values for these properties because the neutronics filters did not require their values at input. Tabulation of these properties highlighted that ternary chloride salts severely lack experimental data.

2.3 THERMOCHEMICAL FILTERS

Understanding the TC nature of the salts is critical to effectively design and operate a chloride blanketed fusion reactor. The chemical properties of high-temperature environments for molten salts are principally dictated by the thermodynamic properties, specifically Gibbs energy functions. By broadly defining a method to characterize the phase equilibria for salt systems, simple—but effective—phase equilibria models can provide necessary characteristics for the salt chemistry of chloride blanket designs.

A variety of chemical characteristics for complex salt mixtures can be generated through equilibrium state functions using the Calculation of Phase Diagrams (CALPHAD) methodology. The CALPHAD approach assumes that the thermodynamic properties of a system are the summative properties of the individual components. Models that use this method first solve for the system-level thermodynamic equilibria, then iteratively adjust the model to fit independent component characteristics that define Gibbs functions. Once defined, the individual component Gibbs functions can be applied in further simulations as sets of functions.

In this study, the commercial software FactSage [17] was integrated with the publicly available MSTDB-TC database [20] to produce phase equilibria for the defined possible salt combinations. FactSage calculates the phase equilibria and thermodynamic properties for a wide variety of multicomponent, multiphase systems and reactions. The MSTDB-TC was developed specifically for molten salt systems, and it includes TC properties of several fuel and coolant salts, consequential fission products and transuranic elements, contaminants such as air and moisture, and likely corrosion product elements. The models and values provided within MSTDB-TC have been obtained through combinations of literature-reported information, first-principles calculations, and experimental measurements that appropriately reproduce the phase equilibria (or phase diagram) and characteristic material property values, such as the liquidus temperature, boiling temperature, heat capacity, enthalpy of mixing, and vapor pressure.

Using the MSTDB-TC database for a targeted set of binary or tertiary chloride salt matrices, several phase equilibria were calculated with the FactSage module Equilib. This module uses the Gibbs energy minimization method to determine the molar amounts of chemical species, partial pressures, and relative mole fractions for heterogeneous equilibrium states of a user-defined chemical matrix over a given temperature range. Chemical equilibrium is calculated by a user-defined definition of any combination of the following parameters: temperature, pressure, volume, enthalpy, and either total or equilibrium activities of any phase constituent in the system. For this investigation, the salt matrix must primarily be in the liquid phase within an operational temperature range without any precipitates.

Binary and tertiary salts were defined by the stoichiometric ratios for each element and input as the specified reactants into an individual Equilib model. The pressure for the isochoric system was then fixed at 1 atm, and each calculation was performed between 400°C and 1,000°C with a step size of 50°C. To specify the calculation of the liquidus temperature, or the minimum temperature to prevent crystallization, each model designated the primary mixture with the solution species indicator of "P," and potential two-phase immiscibility was designated for each component with an indicator of "I." No further constraints were placed on the chemical equilibrium calculations for the salt mixtures, and it is assumed that any quasistatic phase shifts are minimal for the analyzed species. Each salt model was then analyzed to determine the liquidus temperature of the salt matrix.

2.4 NEUTRONICS FILTERS

Desirable neutronic properties included a large tritium production cross section, a large (n, Xn) reaction probability, and low neutron absorption to minimize parasitic loss and activation. Considerations were made to estimate ^{36}Cl production, as well.

Three neutronic filters were applied in this research: a low-cost, medium-cost, and high-cost variant. The low-cost neutronic filter was based on rough assumptions and provided a simplistic understanding of how a chloride-based salt might behave while under bombardment from a fusion flux spectrum. As opposed to medium- and high-cost filters that were too computationally expensive, this filter was computationally cheap and could be performed for all salts. Computational burden per salt is listed in Table 1, where a significant increase in computational burden per salt can be seen as greater fidelity is achieved through the low- to high-cost analyses.

Table 1. Computational burden required to apply each of the neutronic filters, from low- to high-cost

Cost	CPU hours per salt
Low	5×10^{-4}
Medium	24.8
High	49.9

Tritium production can be realized through more than one pathway:

$$\binom{6}{3}Li + n \rightarrow \binom{4}{2}He + \binom{3}{1}H$$
$$\binom{7}{3}Li + n \rightarrow \binom{4}{2}He + \binom{3}{1}H + n$$
$$\binom{10}{5}B + n \rightarrow 2\binom{4}{2}He + \binom{3}{1}H$$
$$\binom{2}{1}H + n \rightarrow \binom{3}{1}H$$

However, the most likely pathway is from the $\binom{6}{3}$Li + n pathway. Low-cost neutronics analysis only considered the $\binom{6}{3}$Li + n pathway, but medium- and high-cost neutronics analysis considered all pathways that cross section information was available for in the ENDF/B-VII.1 nuclear data library [21].

2.4.1 Low-Cost Neutronics Filter

This computationally cheap neutronic filter provides a ranking of salts based on tritium production and a figure of merit (FOM) calculated as

$$TP = \int \boldsymbol{\Sigma}_{^6Li(n,t)}(E)\phi(E)dE, \tag{3}$$

$$NL = \sum_{iso} \int \boldsymbol{\Sigma}_{abs,iso}(E)\phi(E)dE, and \tag{4}$$

$$FOM = \frac{TP}{NL}. \tag{5}$$

In these equations, $\boldsymbol{\Sigma}$ indicates a macroscopic cross section (as opposed to the summation symbol $\sum$), the flux as a function of energy is given as $\phi(E)$, and $\Sigma_{abs,iso} = \Sigma_{\gamma,iso} + \Sigma_{p,iso} + \Sigma_{d,iso} + \Sigma_{\alpha,iso}$, where iso is a variable that represents a given isotope in a molecule (γ, p, d, and α identify cross sections that release gammas, protons, deuterons, and alphas, respectively). The FOM is simply the ratio of tritium production and neutron loss owing to four likely reactions. To calculate the macroscopic cross section, the number density of atoms for each nuclide, N_{iso}, in a material must be known. This, of course, depends on the enrichment or natural abundance of isotopes present in a given element, γ_{iso}, stoichiometry of elements within the molecules present, $stoich_{elem}$, mass fraction of molecules, $MF_{molecule}$, in a molten salt mixture (e.g. 50% LiCl, 50% $AlCl_3$), and the density of the final compound, ρ_{salt}. The product of N_{iso} with the microscopic cross section, $\sigma_{*,iso}$, is macroscopic cross section, or more simply, $\boldsymbol{\Sigma}_{*,\mathbf{iso}} = N_{iso}\sigma_{*,iso}$. For every chloride salt mixture, the following must be done.

1. Define a mass fraction of constituents (referred to as a composition (e.g., 0.5 LiCl and 0.5 $PbCl_2$).
2. Retrieve density information and set ρ_{salt} by
   (a) querying the MSTDB-TP or MSTDB-TC for density information at operating temperature (assume 873 K),
   (b) if said query is unsuccessful, use the ideal density calculation defined in Eq. 2
   (c) if input variables of Eq. 2 are not available, set to default density: 1.97 g/cm^3 for binary mixtures, and 2.03 g/cm^3 for ternary mixtures (the mean value of density successfully found for the other salts by methods above)
3. Calculate number densities of nuclides present based on salt density, ρ_{salt}.
   (a) Calculate molecular (e.g., LiCl) mass density, where MF is mass fraction:

   $$\rho_{molecule} = MF_{molecule} \cdot \rho_{salt} \tag{6}$$

   (b) Calculate the molecular number density, where MM is molar mass, and N_A is Avagadro's number:

   $$N_{molecule} = \frac{\rho_{molecule} \cdot N_A}{MM_{molecule}} \tag{7}$$

(c) Calculate the isotopic number density using the isotopic abundance, γ_{iso}, and the number of elements in the molecule: $stoich_{elem}$,

$$N_{iso} = \gamma_{iso} \cdot stoich_{elem} \cdot N_{molecule} \tag{8}$$

The flux spectrum, $\phi(E)$, for the low-cost neutronics filter was assumed as the shape published by Gilbert et al. [22] for D-T reactions, which is a modeled flux on the first wall of the proposed ITER geometry. An image of their spectrum is given in Figure 3. This flux shape is a simple assumption, which could be improved by modeling the flux in the salt for a given geometry. The simplistic assumption of the first-wall flux spectrum, however, keeps the low-cost neutronic filter computationally inexpensive because the flux would have to be modeled for every geometry and every variation of every salt.

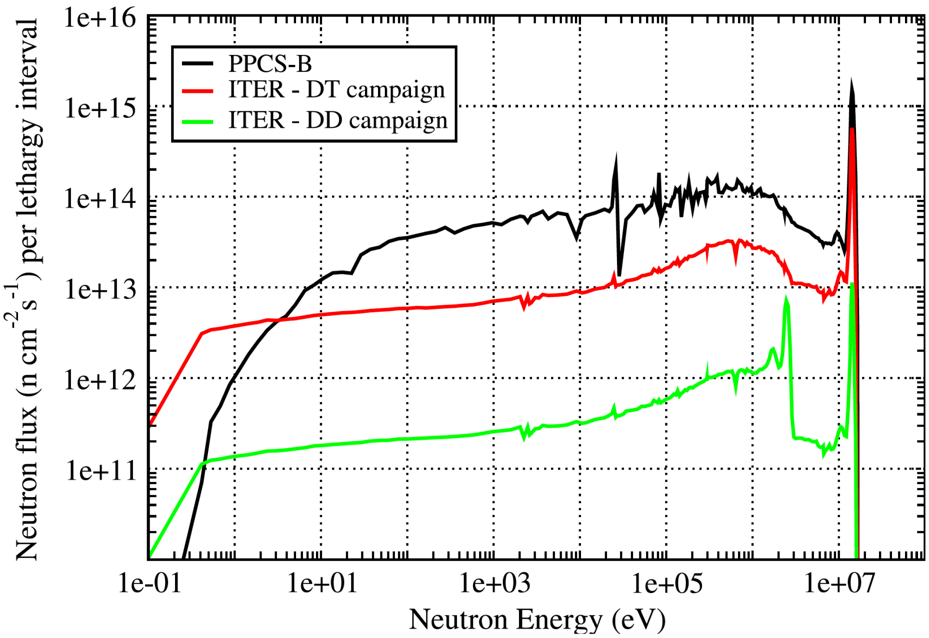


Figure 3. Flux spectra at the first wall in the ITER design, as published by Gilbert et al. [22].

2.4.2 Medium-Cost Neutronics Filter

To perform the medium-cost neutronics filter, two products within the SCALE [11] suite of codes were chosen. The Monte Carlo code Shift [23] was used to generate a flux profile at each time step, which was then fed into the ORIGEN depletion code [24] to output isotopic compositions within the salt.

To reduce computational cost per salt composition simulated, a 1D radial computational domain was selected (Figure 4). A similar approach was also used by Bohm et al. [9], which was published during the course of this study. The 1D simplified domain for this study was based on the Commonwealth Fusion ARC reactor outboard liquid breeder blanket (Figure 5). It was used to calculate tritium production for each salt composition. Because of a lack of proprietary material and dimensional knowledge, the inboard was not modeled in these medium-cost simulations. The Shift 1D representation of the ARC reactor outboard is shown in Figure 6. The full cylinder was run; the quarter symmetry plot is simply for illustration purposes.

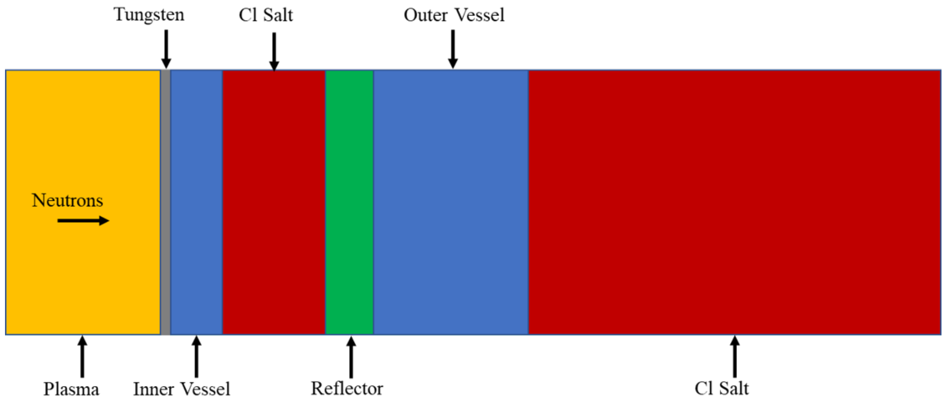


Figure 4. 1D representation the Commonwealth Fusion ARC reactor outboard [25].

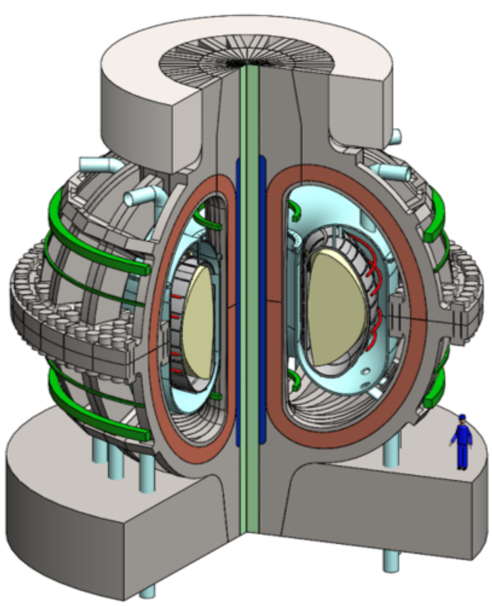


Figure 5. The Commonwealth Fusion ARC reactor [26].

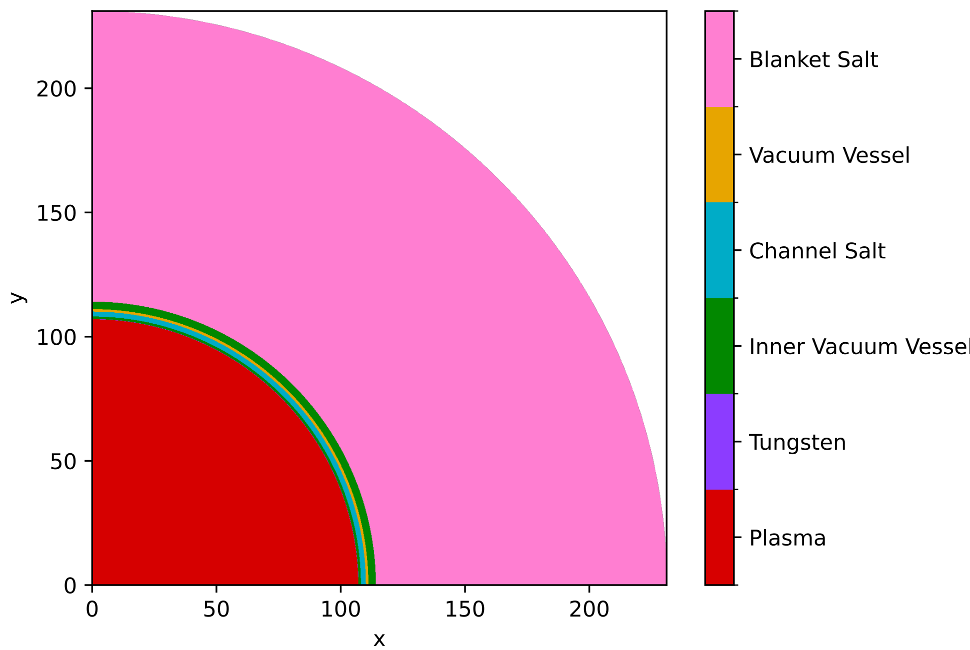


Figure 6. The Shift model geometry (cm) based on the outboard of the Commonwealth Fusion ARC reactor.

Assumptions regarding a fusion reactor operating schedule included quick extraction of tritium from the breeder blanket once a month and that the liquid blanket could remain otherwise unaltered for a year at a time. Following this logic, each composition of the liquid breeder blanket was simulated with Shift and ORIGEN with the following steps (also shown in Figure 7):

1. Start with a fresh chloride salt breeder blanket.
2. Irradiate with a constant source intensity (Equation 9), where the source is 14 MeV neutrons in the Plasma region (see Figure 6) using the Shift Monte Carlo code.
3. Tally the flux in the salt region.
4. Build an ORIGEN depletion library using the flux tally in the salt.
5. Deplete the salt for 1 month with ORIGEN using the built depletion library.
6. Remove tritium from the depleted salt.
7. Begin the next cycle with the depleted salt, and repeat steps 2–5 until 12 months of operation is achieved.

The intensity of 14.06 MeV neutrons is determined from estimates of power output, P, equal to 525 MW published for the ARC reactor [26]. The energy released per D-T fusion event is 14.06 MeV, with one neutron released per fusion event, so the neutron intensity is defined by Equation 9 as

$$I_n = \frac{P\ [\text{J/s}]}{(14.06\ [\text{MeV/n}]) \cdot (1.6021 \cdot 10^{-13}\ [\text{J/MeV}])} = 2.3305 \cdot 10^{20}\ [\text{n/s}] \tag{9}$$

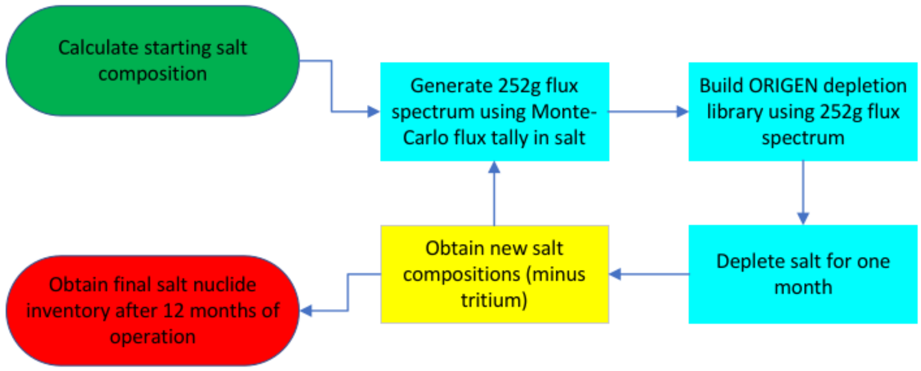


Figure 7. The process to generate salt compositions after 1 year of operation with Shift and ORIGEN.

Notably, all simulations assumed no salt purification over the course of the 12 months of operation.

Consideration of stable isotopic enrichment was also investigated. The key isotopes to enrich to maximum the tritium production using a chloride salt blanket included ^{6}Li and ^{37}Cl. The lithium enrichment activity is synergistic with thermal spectrum fluoride-based molten salt fission reactors. These fission reactors want to avoid tritium production and therefore strongly desire ^{7}Li in their FLiBe salt. Therefore, one separation activity could produce the desired isotopic concentrations for both fission and fusion industries.

Enrichment of ^{37}Cl is advantageous because of the relatively large (n,Xn) cross section and lower epithermal capture cross section compared with the other stable isotope, ^{35}Cl. The chlorine enrichment activity is synergistic with fast-spectrum, chloride-based molten salt fission reactors. Both systems would benefit from enriching ^{37}Cl to avoid parasitic loss of neutrons from the relatively large neutron capture cross section of ^{35}Cl. Having two industries demand this isotope could lead to larger cost savings.

In total, 3 sets of simulations were performed for all salts considered:

1. **Unenriched**: all salts composed of natural abundances of elements
2. **90% ^{37}Cl enriched**: chlorine in the salt has a 90% abundance of ^{37}Cl and 10% abundance of ^{35}Cl
3. **90% ^{37}Cl 90% ^{6}Li enriched**: chlorine in the salt has a 90% abundance of ^{37}Cl and 10% abundance of ^{35}Cl; lithium in the salt has a 90% abundance of ^{6}Li and 10% of ^{7}Li

2.4.3 High-Cost Neutronics Filter

The Fusion Energy Reactor Models Integrator (FERMI) is a multiphysics modeling and simulation framework for fusion reactors [27; 28; 29]. The framework includes basic plasma physics, neutronics, computational fluid dynamics, structural mechanics, and streamlines the process of transferring results from one analysis to the other. The framework also includes a geometry module that automates the cleaning and meshing of CAD geometries and a separate module, Tracer, to generate new CAD models from a parametric description of the reactor geometry.

In this work, the FERMI neutronics module was used. The neutronics module automated the input (including geometry) preparation and output postprocessing and visualization for fusion reactor Monte Carlo neutron and gamma transport simulations. Pertinent metrics were the tritium breeding ratio (TBR) and material activation. The neutronics module can employ any of the three Monte Carlo solvers (OpenMC [30], Shift [31], and MCNP [32]), depending on the user's preference. SCALE/ORIGEN [33] were used for activation.

The neutron transport simulation used the meshed 3D geometry shown in Figure 8 with the DAGMC library [34]. The fusion neutron source is defined within the plasma volume as an isotropic, monoenergetic (14.06 MeV) source. The 3D geometry is a higher fidelity than the low-dimensional models because it models the axial difference of the first wall, as well as the inboard and outboard breeder blankets.

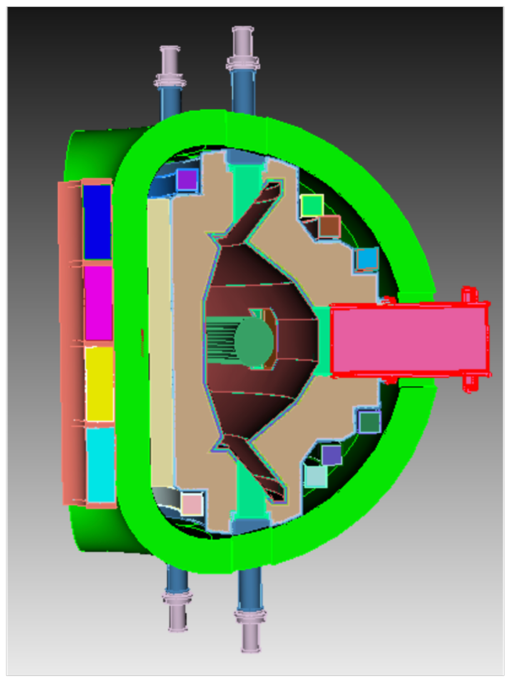


Figure 8. The 3D geometry of the ARC fusion device, visualized in Cubit [35].

To test the performance of each salt composition, the coolant channel and blanket materials are replaced with the salt composition, and the TBR and activation parameters are calculated. The activation is calculated by taking the 252-group, volume-averaged flux spectrum on the coolant channel and blanket, using the 525 MW fusion power scaling factor, and using ORIGEN to calculate the salt composition after 2 effective full-power years.

3. RESULTS

Figure 9 presents the elements that were initially considered to be used to form chloride salt compounds. These chloride salts were compiled based on existing published literature, existing MSTDB-TP and MSTDB-TC database entries, and chemical vendor inventories.

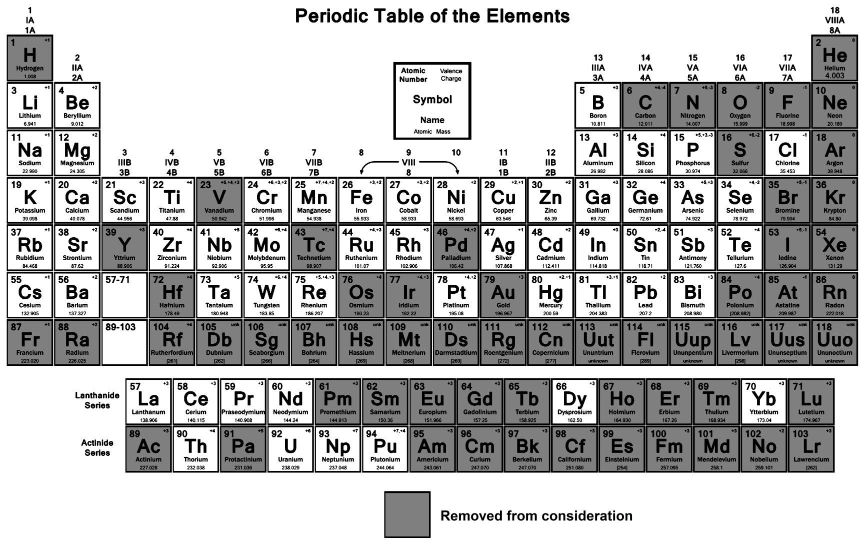


Figure 9. Periodic table with elements under consideration highlighted in white based on existing published literature.

Table 2 presents the number of unique elemental compositions of salts that remained after applying each filter. Because of the near-zero existence of measured TP values for quaternary salts, these salts were removed from consideration after applying the economic filter. Keep in mind that the low- and medium-cost neutronic filters added additional dimensions of varying the weight percent and enrichment. With a 10% step size in weight percent, a total of 9 permutations were considered for each binary salt and 36 permutations for each ternary salt. A total of three enrichment configurations were considered for each chloride salt: natural abundance, 90% enriched ^{37}Cl, and 90% enriched ^{37}Cl and ^{6}Li.

3.1 ECONOMIC CONSIDERATIONS

The economic filters of availability and a price threshold of $1,000/kg were applied to the unfiltered unary list of 79 chloride salts. Of those salts, 49 were removed from consideration, which significantly narrowed

Table 2. The number of unique elemental compositions of salts that remained after applying filters. Values do not account for the permutations of mass fraction and isotopic enrichment for a given unique elemental composition.

Filter	Unary	Binary	Ternary	Quaternary
Raw	79	3,081	79,079	1,502,501
Economic [price, availability]	30	435	4,060	27,405
TP [data availability]	30	435	4,060	N/A
Low-cost neutronic [Li-bearing]	30	29	378	N/A
TC [liquidus]	12	11	34	N/A
Medium-cost neutronic	10	9	10	N/A

the search space. Figure 10 presents the remaining elements under consideration after applying the economic filters.

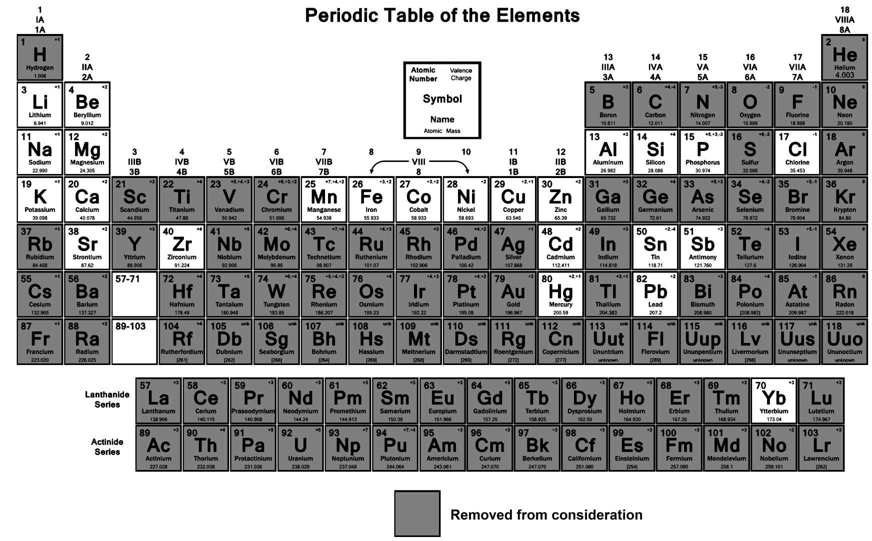


Figure 10. Periodic table with elements under consideration after applying the economic filters.

3.2 VIABILITY BASED ON LIQUIDUS TEMPERATURE

Out of the many available TP and TC filters, the liquidus temperature was employed because of its high importance and ease of applying the Boolean filter criteria. A maximum value was used as a low-pass filter, retaining all salt compositions with liquidus temperatures below 625°C. The 625°C value was selected based on the limitation of high-temperature strength and corrosion resistance of high-Ni alloys, such as Inconel 600 and Alloy C-276 [36; 37], coupled with the assumed requirement of operating the liquid blanket at least 50°C–100°C above the liquidus temperature to avoid inadvertent solid precipitation in the salt. The margin between the liquidus and assumed operating temperatures also allows for salt pumping operations to occur at much lower viscosity values than when operating close to the liquidus temperature. These assumptions eliminated any salt compositions that would force the blanket operating temperature to exceed 725°C. This maximum value is equal to the design value of Facility to Alleviate Salt Technology Risks (FASTR), the state-of-the-art high-temperature chloride salt forced flow loop [38].

With this liquidus low-pass filter, many near-pure salt compositions with high liquidus temperatures were filtered. Figure 11 highlights the remaining elements under consideration after economic and liquidus filters were applied.

No other TP and TC filters were employed before quantifying the low-cost FOM and medium-cost tritium production estimates.

3.3 LOW-COST NEUTRONICS SIMULATIONS

The approach to defining the low-cost neutronics filter can be found in Section 2.4.1. The low-cost neutronics analysis was done for three different assumptions: the mixtures that consisted of elements with natural

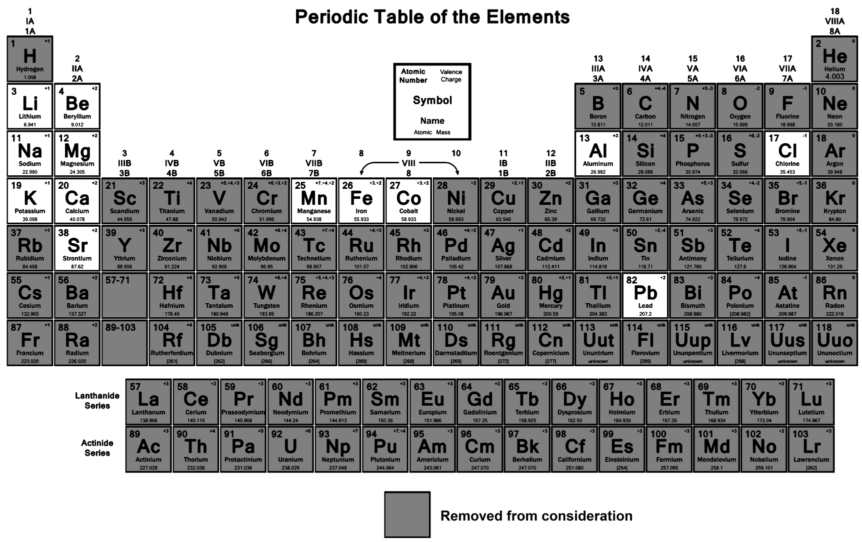


Figure 11. Periodic table with elements under consideration after applying the economic and liquidus temperature filters.

abundance, mixtures using 90% enriched ^{37}Cl, and mixtures using 90% enriched ^{37}Cl and 90% enriched ^{6}Li . One of the biggest filtering criteria that the low-cost neutronics filter enforced was that all Cl-based salt mixtures must contain Li. This criterion, of course, was an expectation and was validated by the analysis.

3.3.1 Binary Salts

The top 30 binary salts sorted by the FOM for each enrichment configuration are plotted in Figures 12, 13, and 14. The top 30 salts change between assumptions of ^{37}Cl enrichment, but the top-performing salt, 90%-LiCl + 10%$PbCl_2$ (by mass fraction), remains the top performer in all three cases.

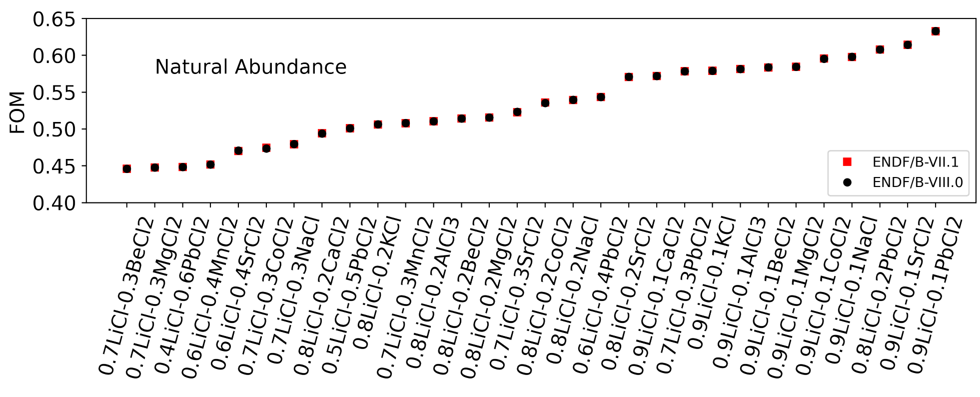


Figure 12. Top 30 binary salts sorted by the FOM assuming a natural abundance of all elements.

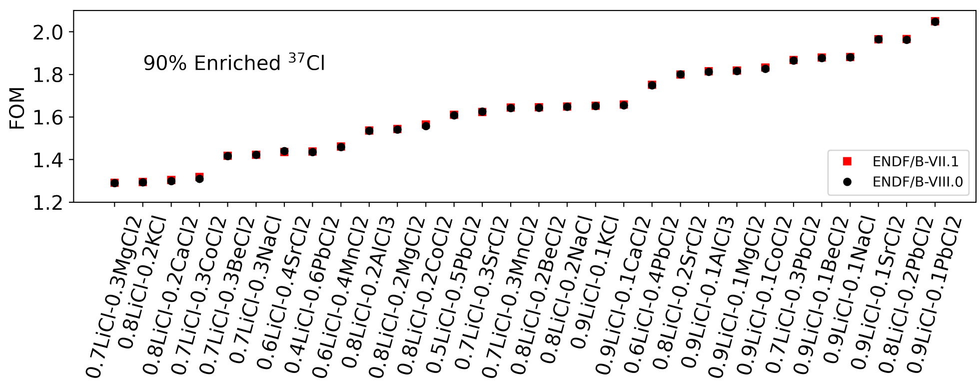


Figure 13. Top 30 binary salts sorted by the FOM assuming a 90% enrichment of ^{37}Cl.

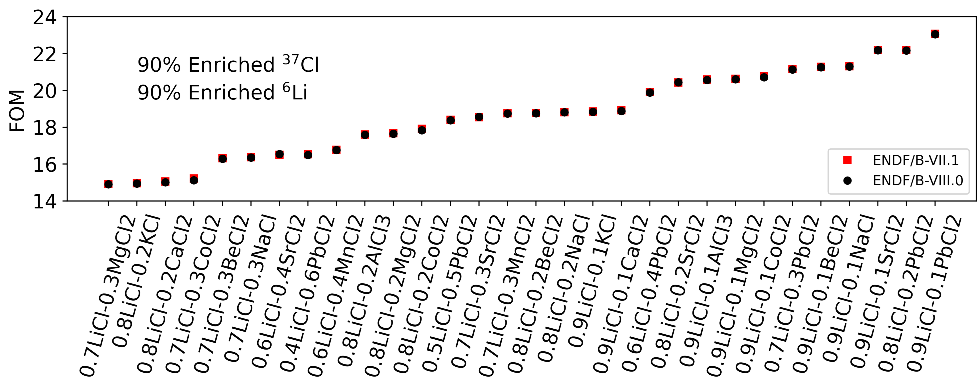


Figure 14. Top 30 binary salts sorted by the FOM assuming a 90% enrichment of ^{37}Cl and ^{6}Li.

Using the low-cost neutronics filter, many salts could be studied using inconsequential computational resources, enabling the investigation of trends and correlations between neutronic responses and salt properties. One hypothesis was that increasing the density of the salt could increase the total number of ^{6}Li atoms and thus improve the total behavior of the salt. Although this hypothesis may still be the case, the results in Figure 15 from the low-cost neutronics calculations show no appreciable correlation between density and the FOM. However, there is a trend toward the density of LiCl, which can also be observed in the previous figures, that very high LiCl concentrations received the highest scoring by the FOM.

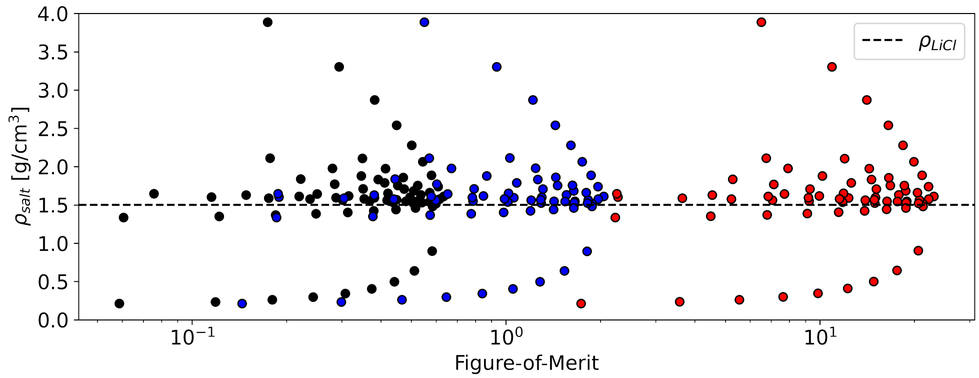


Figure 15. Density as a function of the FOM for binary salts for all three cases: natural abundance, 90% enriched ^{37}Cl, and 90% enriched ^{37}Cl and ^{6}Li—black, blue, and red, respectively. The dashed line indicates the density of LiCl.

However, a positive correlation exists between the liquidus temperature of the salt, $T_{liquidus}$, and the FOM, as seen in Figure 16, with the caveat that it is trending toward the melting temperature of LiCl (indicated by the dashed line). This trend reinforces the need for structural materials that can withstand high-temperature and corrosive environments. There are strong candidate salts with liquidus temperatures close to 525°C, but many promising salt mixtures have values greater than 575°C. The ceiling at 625°C is because of the low-pass liquidus temperature filter defined in Section 2.3, and it should be noted that many high-performing salts were removed from consideration because of that filter.

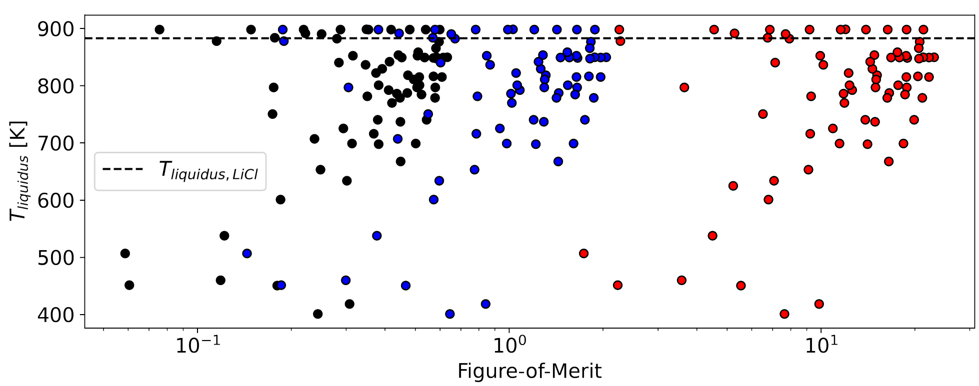


Figure 16. Liquidus temperature as a function of FOM for binary salts for all three cases: natural abundance, 90% enriched ^{37}Cl, and 90% enriched ^{37}Cl and ^{6}Li—black, blue, and red, respectively. The dashed line indicates the liquidus temperature of LiCl.

3.3.2 Ternary Salts

Results from the ternary salts follow similar trends as the binaries. The top 30 ternary salts sorted by FOM for each of the three assumptions are shown in Figures 17, 18, and 19.

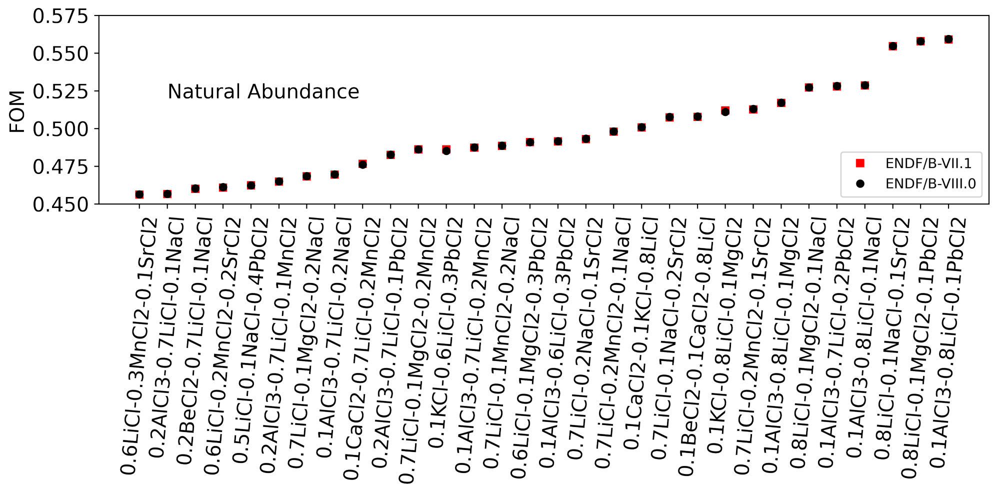


Figure 17. Top 30 ternary salts sorted by the FOM assuming a natural abundance of all elements.

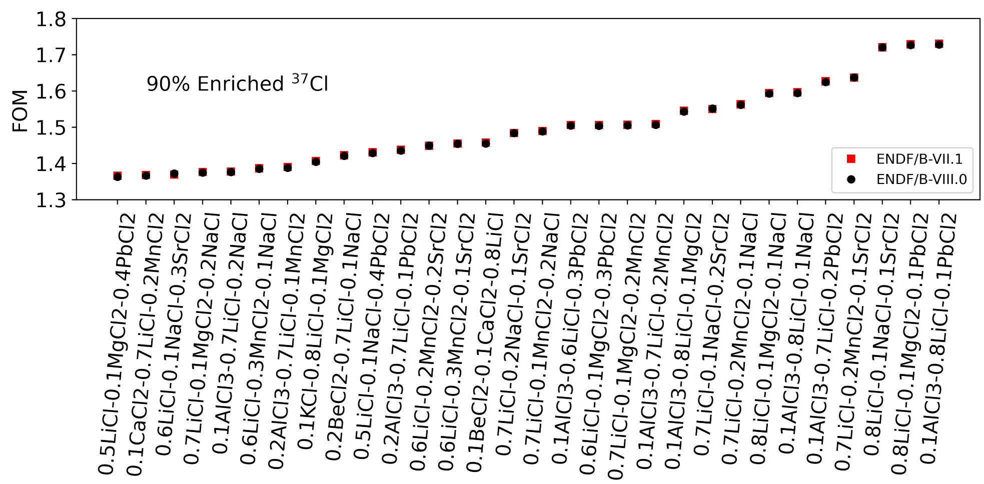


Figure 18. Top 30 ternary salts sorted by the FOM assuming a 90% enrichment of ^{37}Cl.

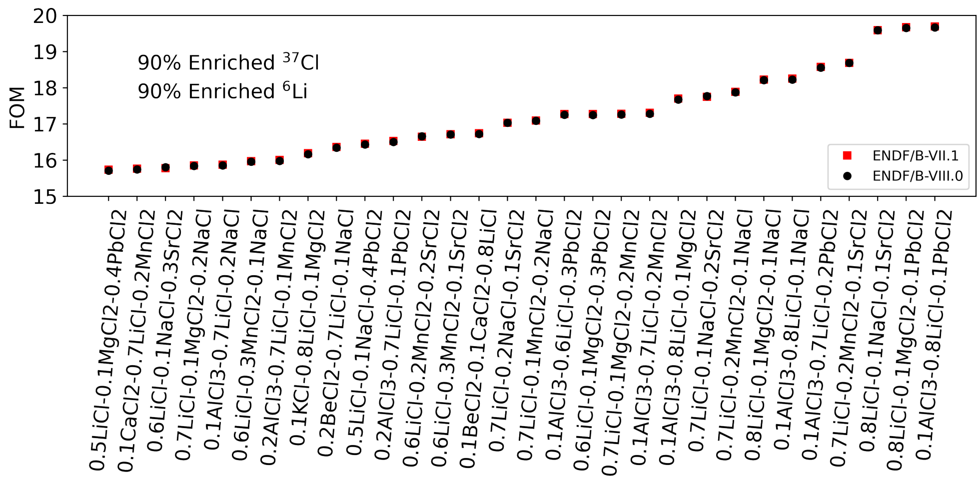


Figure 19. Top 30 ternary salts sorted by the FOM assuming a 90% enrichment of ^{37}Cl and ^{6}Li.

Within the top 30 ternary salts, same as with the binary salts, a clear winner appears no matter the assumptions on isotopic abundance. With the ternary mixtures, the top salt is 80% LiCl + 10% $AlCl_3$ + 10% $PbCl_2$ (by mass fraction). The correlations of density and melting temperature with the FOM are less clear with the ternary salts than with the binaries, but they still exhibit the same trends, as seen in Figures 20 and 21. The structure seen in both the density and melting temperature correlation plots can be attributed to the sampling scheme to determine salt compositions, as 10% step changes in mass fraction were taken. An additional conclusion regarding ternary salts is that relative to binaries, there are salts with lower liquidus temperatures achieving high FOM scores. This behavior implies that ternary salts may provide a pathway toward reducing molten salt blanket operating temperatures.

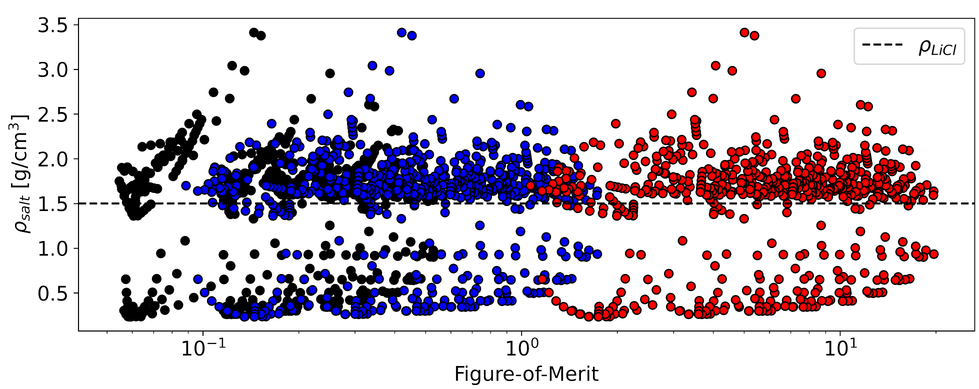


Figure 20. Density as a function of FOM for ternary salts for all three cases: natural abundance, 90% enriched ^{37}Cl, and 90% enriched ^{37}Cl and ^{6}Li—black, blue, and red, respectively. The dashed line indicates the density of LiCl.

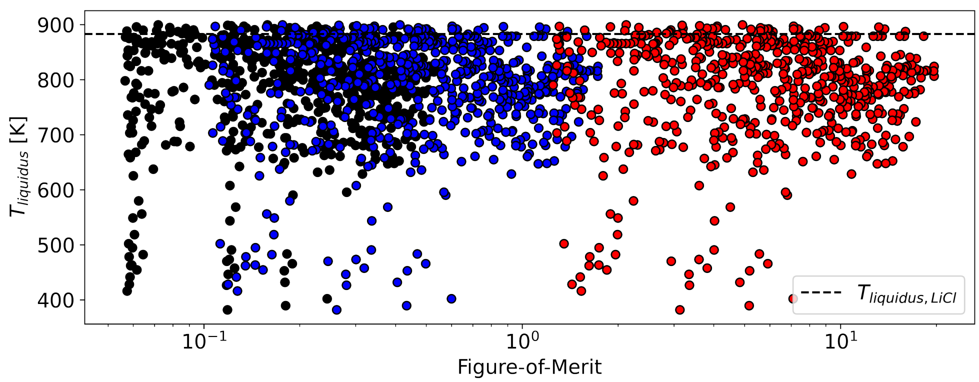


Figure 21. Liquidus temperature as a function of FOM for ternary salts for all three cases: natural abundance, 90% enriched ^{37}Cl, and 90% enriched ^{37}Cl and ^{6}Li—black, blue, and red, respectively. The dashed line indicates the liquidus temperature of LiCl.

3.3.3 Trends in Low-Cost Neutronic Analysis

All binary and ternary salts, considering all enrichment configurations, were combined into one data set and sorted by the FOM to determine the best salts according to the low-cost neutronic analysis (Figure 22). Notably, all of the top 30 salts sorted by the FOM have 90% enriched ^{37}Cl and ^{6}Li.

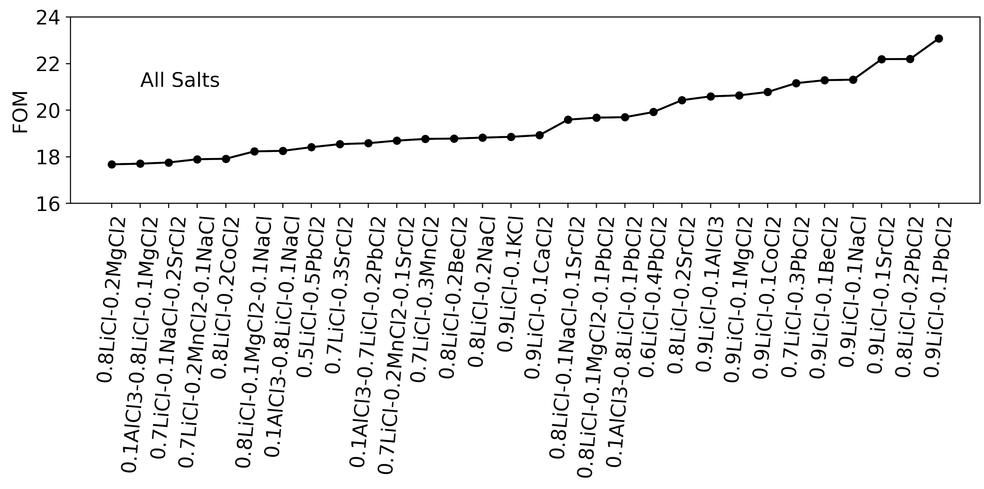


Figure 22. All binary and ternary salts, considering all enrichment configurations, were sorted by the FOM. The top 30 are presented here, with binary mixtures for all of the top 10. Only salts with 90% enriched ^{37}Cl and ^{6}Li made the top 30.

Based on the previous results for binary and ternary mixtures compared only with themselves, it would be natural to assume that the Li content is the strongest driving factor for salt performance because for binary mixtures, a 90% LiCl salt (highest fraction for binary) was the best, and for ternary mixtures, an 80% LiCl salt (highest fraction for ternary) was the best. Comparing these salts together presents a more complete picture. However, the best ternary mixture (80% LiCl + 10% $AlCl_3$ + 10% $PbCl_2$) was shown to be underperforming compared with the binary mixture 60% LiCl + 40% $PbCl_2$. This underperformance is driven by density differences and low absorption of Pb isotopes.

The same diluent molecules were shown to rise to the top (based on FOM) for the binary and ternary mixtures—$MgCl_2$, $PbCl_2$, NaCl, and $SrCl_2$ among the most important. Some of this can be attributed to low neutron loss owing to neutron capture in Mg, Pb, Sr, and Na. The capture cross sections for major isotopes of these three elements are shown in Figure 23. Only ^{23}Na, ^{86,87}Sr, and ^{207}Pb capture cross sections are larger than ^{37}Cl in the epithermal neutron energy range (<1 keV in Figure 23), and none of them have capture cross sections greater than ^{35}Cl in that energy region.

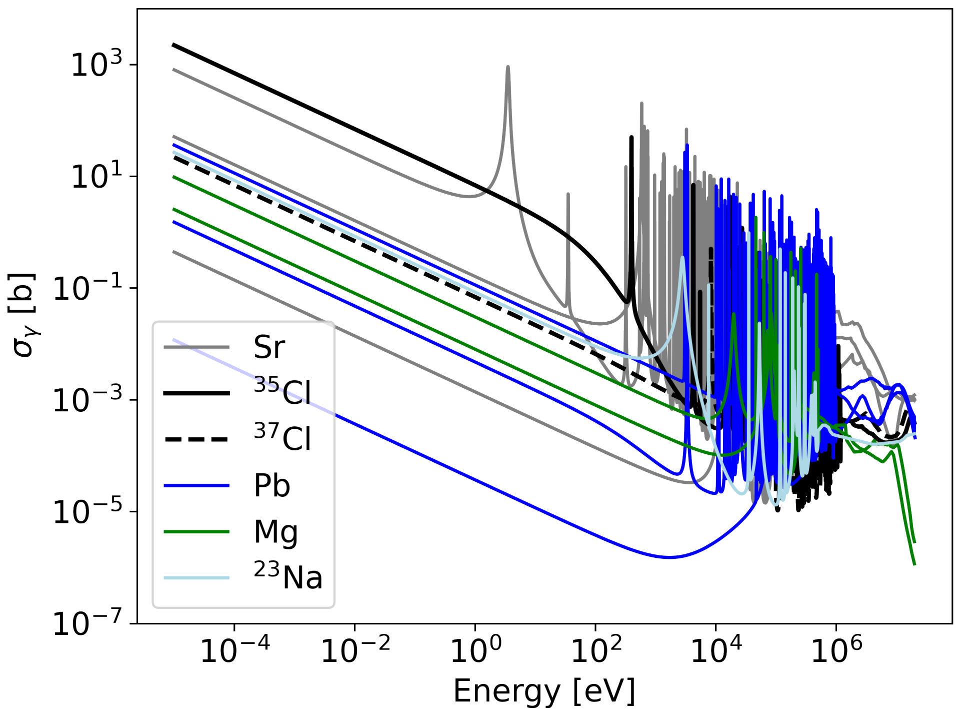


Figure 23. The capture cross section of the top four best-performing LiCl diluents. The capture cross sections of all four are lower than ^{35}Cl, and only ^{23}Na, ^{86,87}Sr, and ^{207}Pb capture cross sections are larger than ^{37}Cl when neutrons become thermalized.

Other poison reactions considered for the low-cost neutronic analysis were (n, p), (n, d), and (n, α) which are plotted below in Figure 24. These cross sections, while small, play an important role because they peak close to the maximum flux for the assumed flux energy spectrum. For reference, the flux used in the calculation of the FOM is shown in Figure 24, as well. Again, ^{35}Cl has the greatest probability for absorbing neutrons among the top-performing salts.

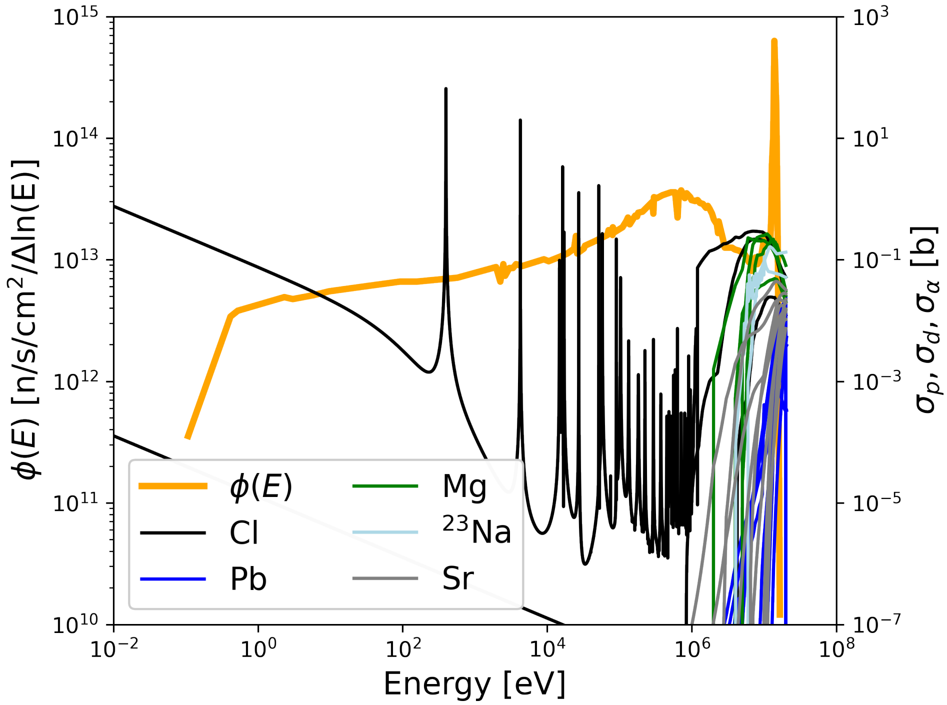


Figure 24. The (n, p), (n, d), and (n, α) cross sections (where available) of the top three best-performing LiCl diluents. These cross sections peak near the maximum flux at ~14 MeV.

The $(n, 2n)$ reaction is also very important to consider in a neutronics analysis. The $(n, 2n)$ cross sections for some of the top performing LiCl diluents are plotted in Figure 25. Pb, Mg, and Sr all have strong $(n, 2n)$ cross sections that will boost their performance more in the medium- and high-cost analysis in the following sections of this report.

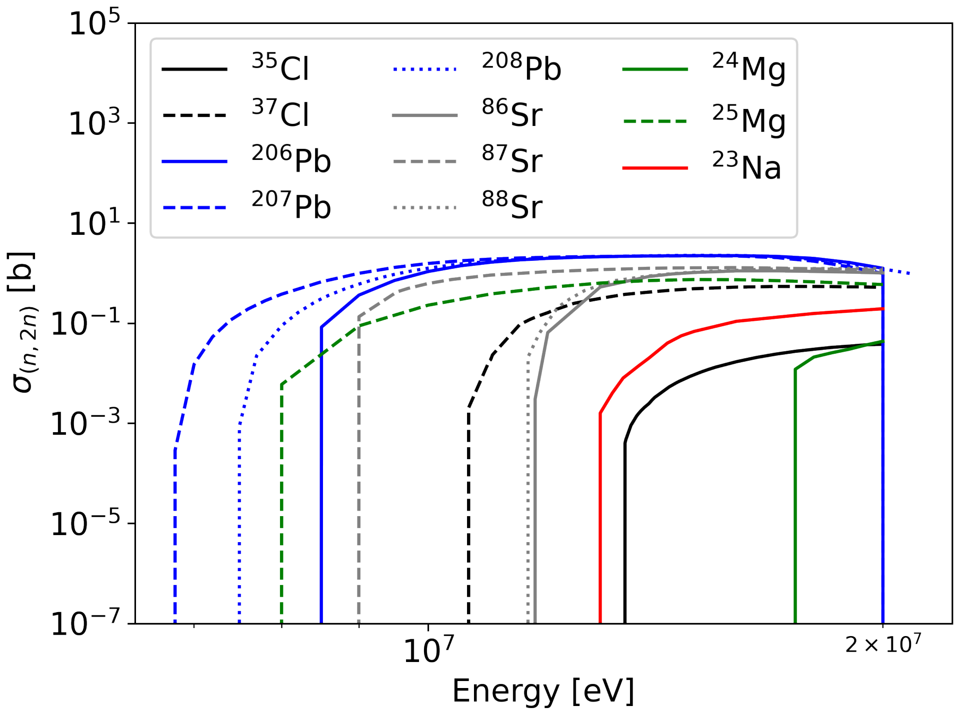


Figure 25. The $(n, 2n)$ cross sections of the top four best-performing LiCl diluents. These cross sections peak near the maximum flux at ~14 MeV.

A summary of the findings for the low-cost neutronics analysis suggests that the best-performing binary salt is 90% LiCl + 10% $PbCl_2$, and the best-performing ternary salt was 80% LiCl + 10% $AlCl_3$ + 10% $PbCl_2$. These performances are driven by the high ^{6}Li content and low absorption cross section of non-^{6}Li nuclides. In future investigations, other forms of the FOM could be investigated to incorporate the value of neutron multiplying cross sections—for example,

$$FOM = \frac{\int \Sigma_{^6Li(n,t)}(E)\phi(E)\left(1 + \sum_{iso} \frac{\Sigma_{(n,2n),iso}(E)}{\sum_{iso}\Sigma_{tot,iso}(E)}\right)dE}{\sum_{iso}\int \Sigma_{abs,iso}(E)\phi(E)dE}. \tag{10}$$

3.4 MEDIUM-COST NEUTRONICS SIMULATIONS

The approach to defining the medium-cost neutronics filter can be found in Section 2.4.2. The simulation results were processed after performing the Shift Monte Carlo simulations. For each salt, the primary quantity of interest was quantified by calculating the total tritium generation over the irradiation time and then normalizing production for each chloride salt by the total tritium generated using FLiBe as the liquid breeder benchmark material.

3.4.1 Binary Salts

The binary salts with tritium production greater than FLiBe with 90% ^{6}Li atomic enrichment are shown in Figure 26 and tabulated in Table 3. The tritium production of the unenriched chloride salts was approximately 65% of that for unenriched FLiBe. Tritium production was increased by approximately 10% when enriching the chloride salts to 90% atomic ^{37}Cl. The most significant increase in chloride salt tritium production occurred when simultaneously enriching ^{37}Cl and ^{6}Li. In this scenario, chloride salt tritium production ratios were achieved with upward of 19% greater than that of unenriched FLiBe.

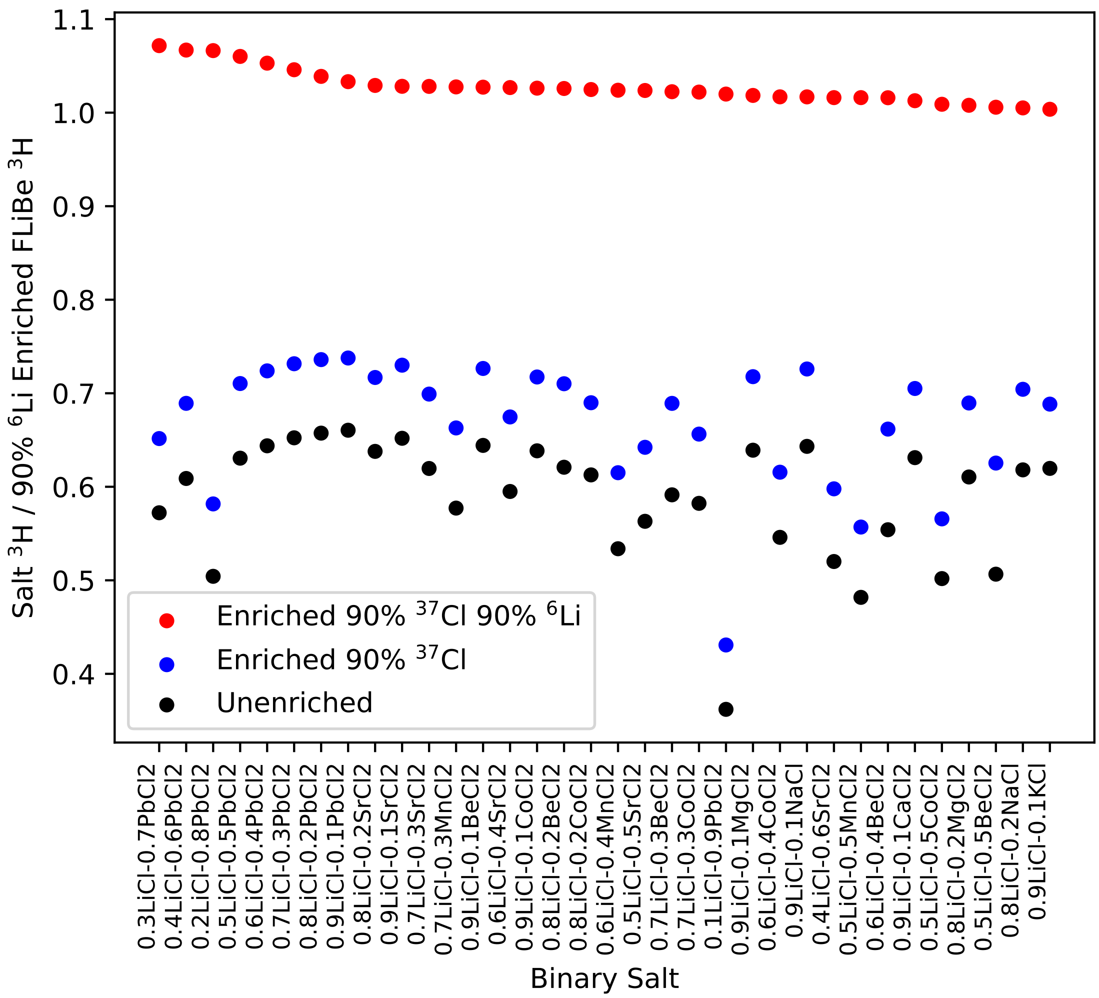


Figure 26. The binary salts' tritium production normalized to 90% atomically enriched FLiBe.

Table 3. The binary salt tritium production normalized to 90% ^{6}Li enriched FLiBe tritium production.

Salt	Unenriched	90% Enriched ^{37}Cl	90% Enriched ^{6}Li-^{37}Cl
0.3LiCl-0.7PbCl2	0.572220	0.651560	1.071670
0.4LiCl-0.6PbCl2	0.608880	0.689210	1.066930
0.2LiCl-0.8PbCl2	0.504260	0.581680	1.066360
0.5LiCl-0.5PbCl2	0.630580	0.710390	1.060140
0.6LiCl-0.4PbCl2	0.643820	0.723940	1.052930
0.7LiCl-0.3PbCl2	0.652360	0.731560	1.045910
0.8LiCl-0.2PbCl2	0.657350	0.735970	1.038800
0.9LiCl-0.1PbCl2	0.660460	0.737680	1.033160
0.8LiCl-0.2SrCl2	0.637840	0.716860	1.029120
0.9LiCl-0.1SrCl2	0.651850	0.730010	1.028180
0.7LiCl-0.3SrCl2	0.619570	0.699100	1.028090
0.7LiCl-0.3MnCl2	0.577200	0.662910	1.027550
0.9LiCl-0.1BeCl2	0.644240	0.726500	1.027260
0.6LiCl-0.4SrCl2	0.594980	0.674670	1.026850
0.9LiCl-0.1CoCl2	0.638460	0.717390	1.026210
0.8LiCl-0.2BeCl2	0.620890	0.710180	1.025860
0.8LiCl-0.2CoCl2	0.612710	0.689870	1.024740
0.6LiCl-0.4MnCl2	0.533760	0.615050	1.023990
0.5LiCl-0.5SrCl2	0.563080	0.642200	1.023720
0.7LiCl-0.3BeCl2	0.591400	0.689170	1.022420
0.7LiCl-0.3CoCl2	0.582290	0.656320	1.022010
0.1LiCl-0.9PbCl2	0.362030	0.430850	1.019880
0.9LiCl-0.1MgCl2	0.639100	0.717740	1.018440
0.6LiCl-0.4CoCl2	0.545930	0.615580	1.016930
0.9LiCl-0.1NaCl	0.643210	0.725940	1.016890
0.4LiCl-0.6SrCl2	0.520090	0.597810	1.016100
0.5LiCl-0.5MnCl2	0.481770	0.556940	1.016090
0.6LiCl-0.4BeCl2	0.554070	0.661680	1.015970
0.9LiCl-0.1CaCl2	0.631160	0.705100	1.012790
0.5LiCl-0.5CoCl2	0.501840	0.565690	1.008980
0.8LiCl-0.2MgCl2	0.610480	0.689580	1.007880
0.5LiCl-0.5BeCl2	0.506550	0.625350	1.005820
0.8LiCl-0.2NaCl	0.618090	0.704230	1.005100
0.9LiCl-0.1KCl	0.619660	0.688370	1.003630

Figure 27 and Table 4 show the top binary salts' total tritium production normalized to the total tritium production in unenriched FLiBe. By changing the normalization variable from unenriched FLiBe to enriched FLiBe, the relative performance of each chloride salt series decreases by approximately 10%. However, nearly 34 binary chloride salts had higher tritium production than 90% enriched FLiBe, with the best binary chloride salt achieving 7% more tritium production than 90% enriched FLiBe.

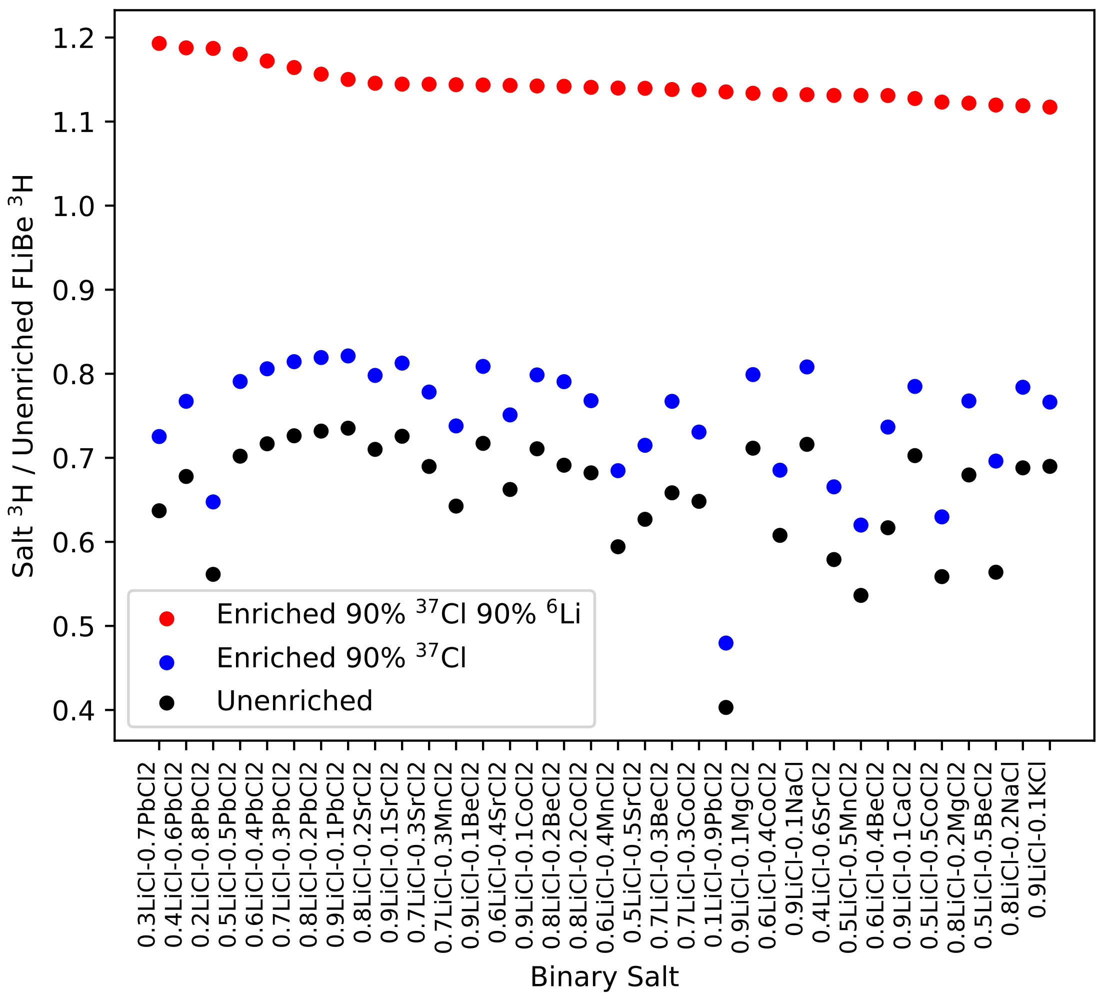


Figure 27. The binary salts' tritium production normalized to unenriched FLiBe.

Table 4. The binary salt tritium production normalized to unenriched FLiBe tritium production.

Salt	Unenriched	90% Enriched ^{37}Cl	90% Enriched ^{6}Li-^{37}Cl
0.3LiCl-0.7PbCl2	0.637000	0.725320	1.192990
0.4LiCl-0.6PbCl2	0.677810	0.767230	1.187720
0.2LiCl-0.8PbCl2	0.561350	0.647530	1.187070
0.5LiCl-0.5PbCl2	0.701960	0.790810	1.180160
0.6LiCl-0.4PbCl2	0.716700	0.805900	1.172120
0.7LiCl-0.3PbCl2	0.726210	0.814370	1.164320
0.8LiCl-0.2PbCl2	0.731770	0.819290	1.156400
0.9LiCl-0.1PbCl2	0.735230	0.821190	1.150120
0.8LiCl-0.2SrCl2	0.710040	0.798010	1.145620
0.9LiCl-0.1SrCl2	0.725640	0.812660	1.144580
0.7LiCl-0.3SrCl2	0.689710	0.778240	1.144480
0.7LiCl-0.3MnCl2	0.642550	0.737950	1.143870
0.9LiCl-0.1BeCl2	0.717170	0.808750	1.143550
0.6LiCl-0.4SrCl2	0.662340	0.751050	1.143090
0.9LiCl-0.1CoCl2	0.710730	0.798600	1.142380
0.8LiCl-0.2BeCl2	0.691180	0.790580	1.141990
0.8LiCl-0.2CoCl2	0.682080	0.767970	1.140750
0.6LiCl-0.4MnCl2	0.594190	0.684680	1.139910
0.5LiCl-0.5SrCl2	0.626820	0.714900	1.139610
0.7LiCl-0.3BeCl2	0.658350	0.767190	1.138170
0.7LiCl-0.3CoCl2	0.648210	0.730620	1.137710
0.1LiCl-0.9PbCl2	0.403020	0.479630	1.135330
0.9LiCl-0.1MgCl2	0.711450	0.799000	1.133730
0.6LiCl-0.4CoCl2	0.607730	0.685270	1.132060
0.9LiCl-0.1NaCl	0.716030	0.808120	1.132010
0.4LiCl-0.6SrCl2	0.578960	0.665480	1.131130
0.5LiCl-0.5MnCl2	0.536310	0.619980	1.131120
0.6LiCl-0.4BeCl2	0.616790	0.736590	1.130990
0.9LiCl-0.1CaCl2	0.702610	0.784920	1.127440
0.5LiCl-0.5CoCl2	0.558650	0.629720	1.123210
0.8LiCl-0.2MgCl2	0.679590	0.767640	1.121980
0.5LiCl-0.5BeCl2	0.563890	0.696140	1.119690
0.8LiCl-0.2NaCl	0.688060	0.783950	1.118880
0.9LiCl-0.1KCl	0.689810	0.766290	1.117250

3.4.2 Ternary Salts

Figure 28 and Table 5 show the ternary salts' total tritium production normalized to the total tritium production in FLiBe with 90% ^{6}Li atomic enrichment. Although the ternary salts generally do not perform as well as the binary salts, these results strongly emphasize that many ternary chloride salt mixtures exist that have the potential to equal and surpass enriched FLiBe tritium production while avoiding the use of Be.

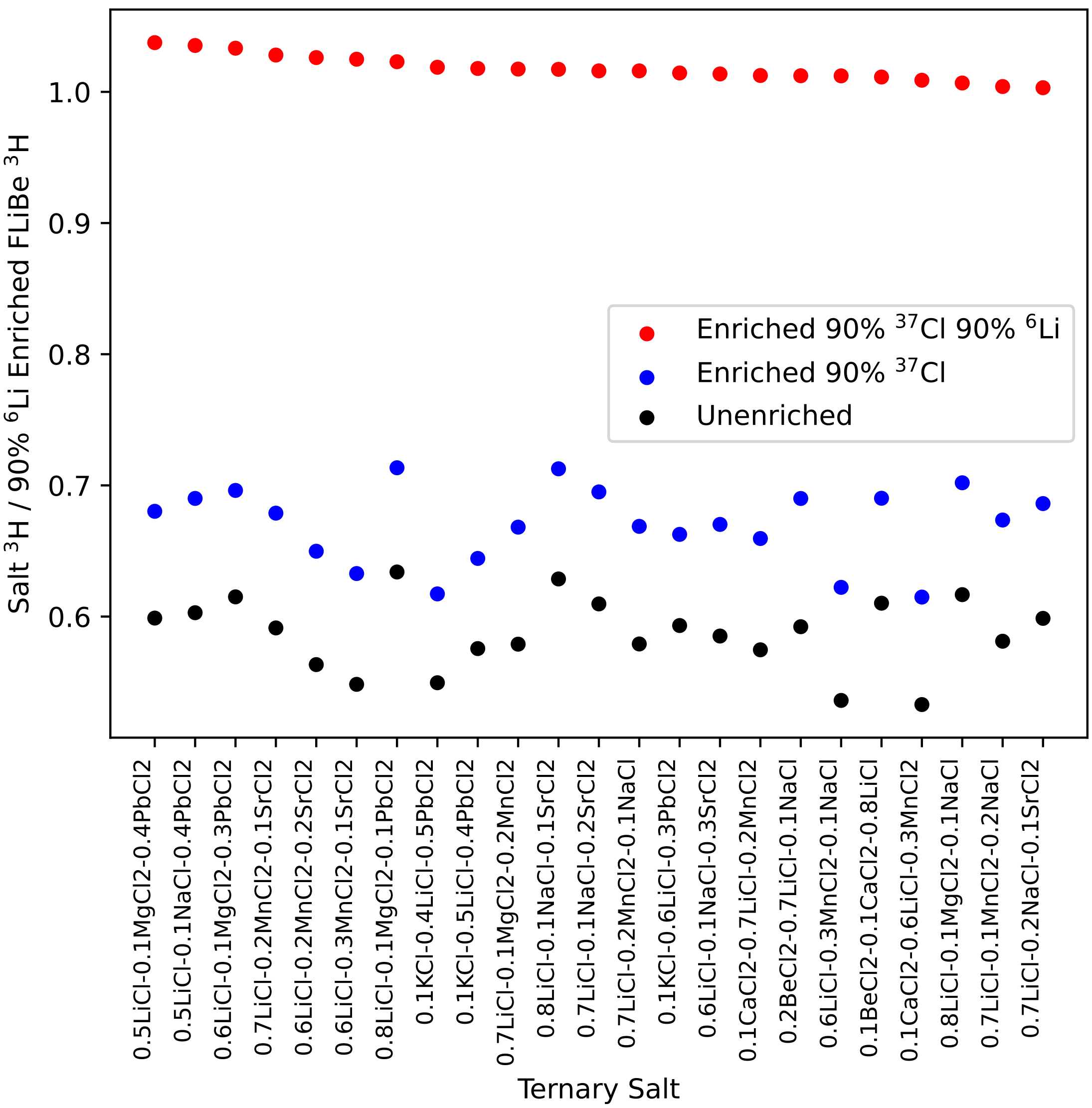


Figure 28. The ternary salts' tritium production normalized to 90% atomically enriched FLiBe.

Table 5. The ternary salt tritium production normalized to 90% ^{6}Li enriched FLiBe tritium production.

Salt	Unenriched	90% Enriched ^{37}Cl	90% Enriched ^{6}Li-^{37}Cl
0.5LiCl-0.1MgCl2-0.4PbCl2	0.598850	0.680240	1.037530
0.5LiCl-0.1NaCl-0.4PbCl2	0.602930	0.690070	1.035360
0.6LiCl-0.1MgCl2-0.3PbCl2	0.615020	0.696170	1.033290
0.7LiCl-0.2MnCl2-0.1SrCl2	0.591340	0.678850	1.028070
0.6LiCl-0.2MnCl2-0.2SrCl2	0.563390	0.649800	1.026150
0.6LiCl-0.3MnCl2-0.1SrCl2	0.548330	0.632800	1.024890
0.8LiCl-0.1MgCl2-0.1PbCl2	0.633980	0.713440	1.022980
0.1KCl-0.4LiCl-0.5PbCl2	0.549550	0.617280	1.018760
0.1KCl-0.5LiCl-0.4PbCl2	0.575600	0.644320	1.017850
0.7LiCl-0.1MgCl2-0.2MnCl2	0.578960	0.668170	1.017380
0.8LiCl-0.1NaCl-0.1SrCl2	0.628670	0.712650	1.017180
0.7LiCl-0.1NaCl-0.2SrCl2	0.609640	0.695040	1.016020
0.7LiCl-0.2MnCl2-0.1NaCl	0.579110	0.668770	1.016010
0.1KCl-0.6LiCl-0.3PbCl2	0.593160	0.662660	1.014400
0.6LiCl-0.1NaCl-0.3SrCl2	0.585160	0.670250	1.013670
0.1CaCl2-0.7LiCl-0.2MnCl2	0.574650	0.659510	1.012470
0.2BeCl2-0.7LiCl-0.1NaCl	0.592270	0.690030	1.012300
0.6LiCl-0.3MnCl2-0.1NaCl	0.536070	0.622270	1.012210
0.1BeCl2-0.1CaCl2-0.8LiCl	0.610200	0.690200	1.011330
0.1CaCl2-0.6LiCl-0.3MnCl2	0.532920	0.614850	1.008880
0.8LiCl-0.1MgCl2-0.1NaCl	0.616710	0.702000	1.006760
0.7LiCl-0.1MnCl2-0.2NaCl	0.581200	0.673600	1.004070
0.7LiCl-0.2NaCl-0.1SrCl2	0.598630	0.686140	1.003160

Figure 29 and Table 6 show the ternary salts' total tritium production normalized to the total tritium production in unenriched FLiBe. Compared with the performance observed in Figure 27, the ternary chloride salts achieved slightly lower performance than the binary chloride salts but were still above unenriched FLiBe for the chloride salts atomically enriched to 90% in both ^{37}Cl and ^{6}Li.

Table 6. The ternary salt tritium production normalized to unenriched FLiBe tritium production.

Salt	Unenriched	90% Enriched ^{37}Cl	90% Enriched ^{6}Li-^{37}Cl
0.5LiCl-0.1MgCl2-0.4PbCl2	0.666640	0.757250	1.154980
0.5LiCl-0.1NaCl-0.4PbCl2	0.671180	0.768190	1.152570
0.6LiCl-0.1MgCl2-0.3PbCl2	0.684650	0.774980	1.150270
0.7LiCl-0.2MnCl2-0.1SrCl2	0.658280	0.755700	1.144450
0.6LiCl-0.2MnCl2-0.2SrCl2	0.627160	0.723360	1.142320
0.6LiCl-0.3MnCl2-0.1SrCl2	0.610400	0.704440	1.140910
0.8LiCl-0.1MgCl2-0.1PbCl2	0.705750	0.794210	1.138780

Continued on next page

Table 6. The ternary salt tritium production normalized to unenriched FLiBe tritium production.

Salt	Unenriched	90% Enriched ^{37}Cl	90% Enriched ^{6}Li-^{37}Cl
0.1KCl-0.4LiCl-0.5PbCl2	0.611770	0.687160	1.134090
0.1KCl-0.5LiCl-0.4PbCl2	0.640760	0.717260	1.133080
0.7LiCl-0.1MgCl2-0.2MnCl2	0.644500	0.743810	1.132560
0.8LiCl-0.1NaCl-0.1SrCl2	0.699840	0.793320	1.132330
0.7LiCl-0.1NaCl-0.2SrCl2	0.678660	0.773720	1.131040
0.7LiCl-0.2MnCl2-0.1NaCl	0.644670	0.744480	1.131030
0.1KCl-0.6LiCl-0.3PbCl2	0.660310	0.737670	1.129240
0.6LiCl-0.1NaCl-0.3SrCl2	0.651400	0.746130	1.128430
0.1CaCl2-0.7LiCl-0.2MnCl2	0.639710	0.734170	1.127090
0.2BeCl2-0.7LiCl-0.1NaCl	0.659320	0.768140	1.126900
0.6LiCl-0.3MnCl2-0.1NaCl	0.596760	0.692720	1.126800
0.1BeCl2-0.1CaCl2-0.8LiCl	0.679280	0.768340	1.125820
0.1CaCl2-0.6LiCl-0.3MnCl2	0.593250	0.684450	1.123090
0.8LiCl-0.1MgCl2-0.1NaCl	0.686520	0.781480	1.120730
0.7LiCl-0.1MnCl2-0.2NaCl	0.646990	0.749850	1.117740
0.7LiCl-0.2NaCl-0.1SrCl2	0.666390	0.763820	1.116720

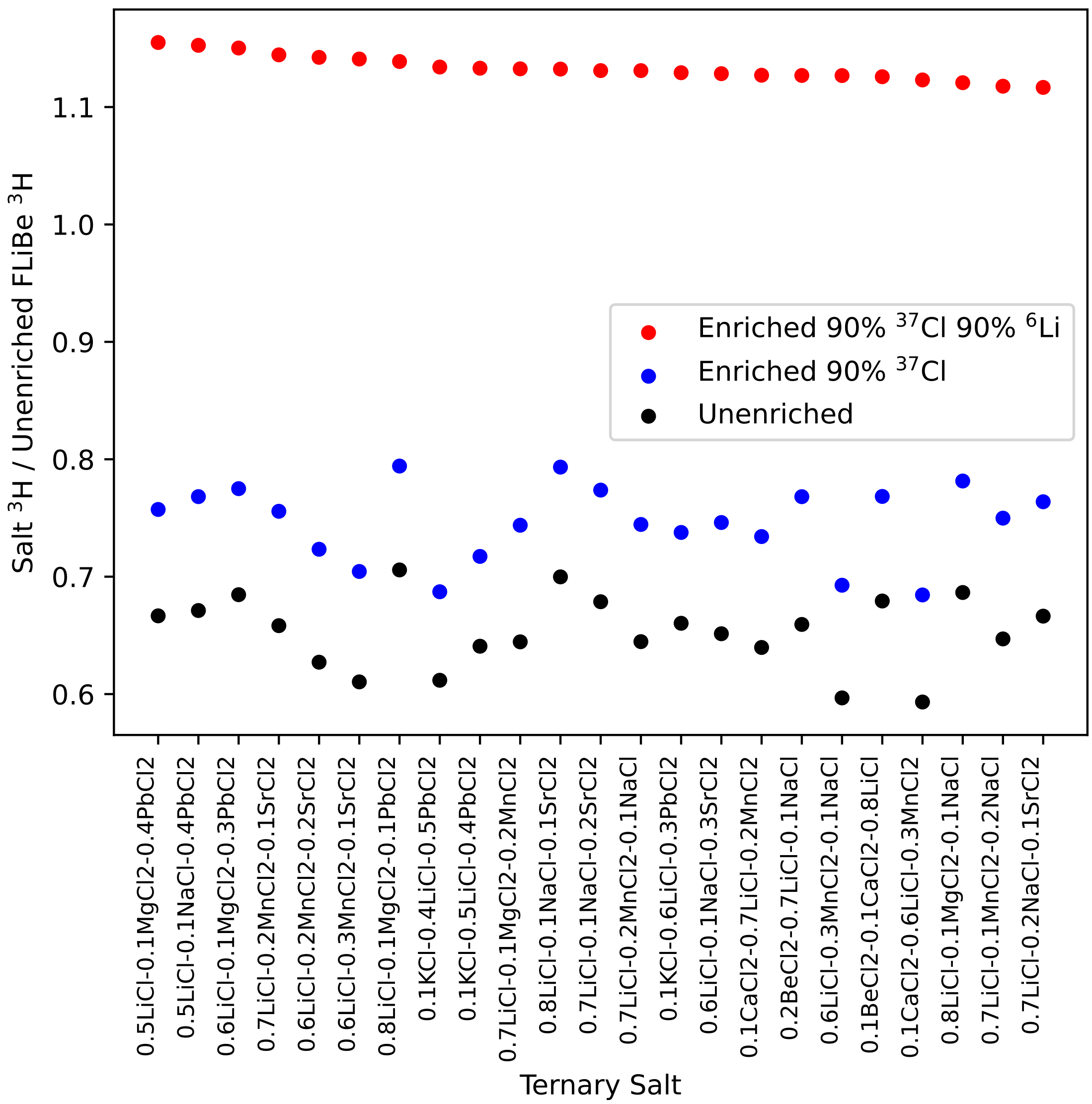


Figure 29. The ternary salts' tritium production normalized to unenriched FLiBe.

3.4.3 Production of ^{36}Cl

Figure 30 and Table 7 show the ratio of tritium production to ^{36}Cl production sorted in descending order of tritium production with the highest-performing salt listed at the top of each table. The general trend of these results highlights the inverse relationship that as tritium production decreases, ^{36}Cl production increases. Notably, various binary salt compositions with $MnCl_2$ appear as outliers with low ^{36}Cl production.

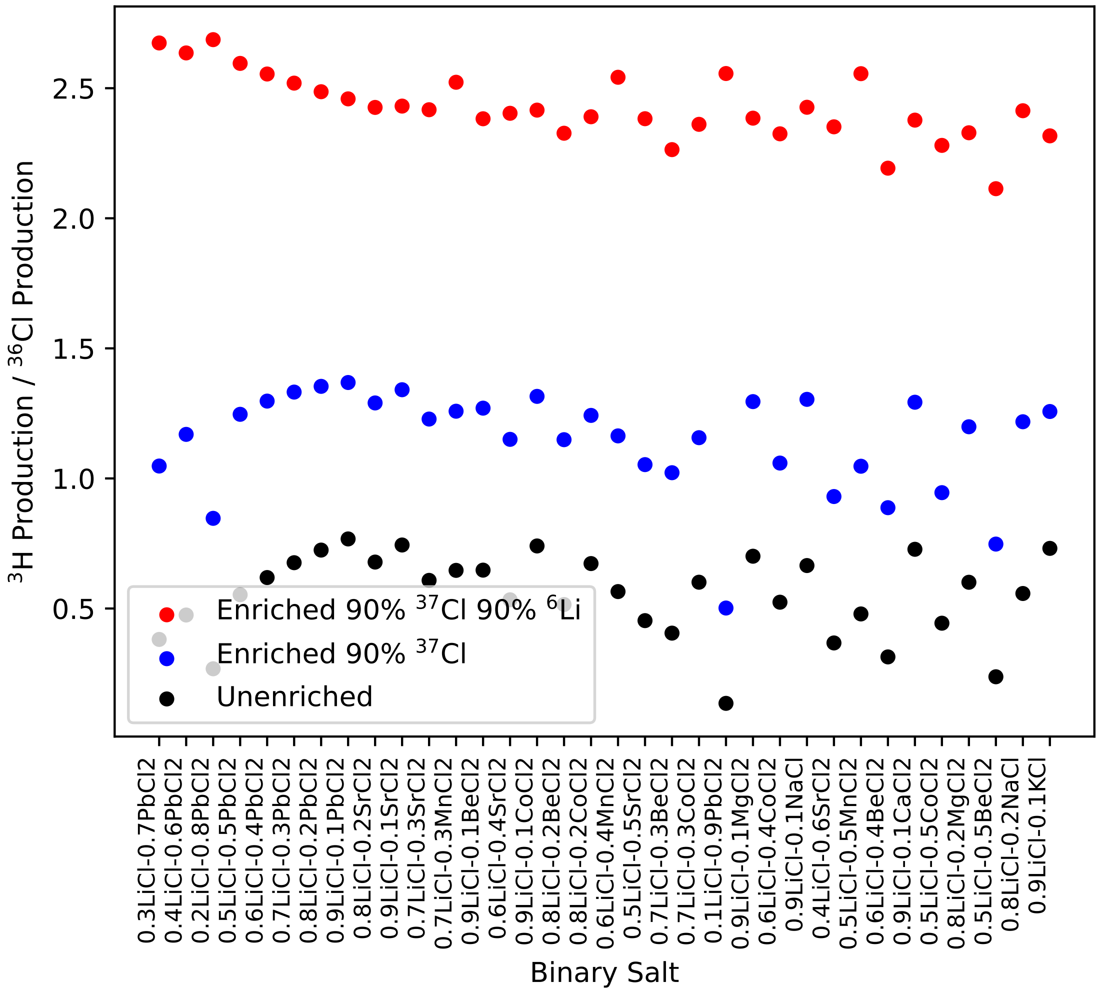


Figure 30. The binary salts' tritium production to 36Cl production ratio.

Table 7. The ratio of ^{3}H production to ^{36}Cl production in each salt.

Salt	Unenriched	90% Enriched ^{37}Cl	90% Enriched ^{6}Li-^{37}Cl
0.3LiCl-0.7PbCl2	0.381159	1.047663	2.673887
0.4LiCl-0.6PbCl2	0.475001	1.169339	2.635615
0.2LiCl-0.8PbCl2	0.268353	0.846603	2.686655

Continued on next page

Table 7. **The ratio of ^3H production to ^{36}Cl production in each salt.**

Salt	Unenriched	90% Enriched ^{37}Cl	90% Enriched ^6Li-^{37}Cl
0.5LiCl-0.5PbCl2	0.553035	1.246449	2.595358
0.6LiCl-0.4PbCl2	0.619020	1.297262	2.554568
0.7LiCl-0.3PbCl2	0.676097	1.331909	2.519509
0.8LiCl-0.2PbCl2	0.724560	1.353954	2.486518
0.9LiCl-0.1PbCl2	0.767448	1.368696	2.459034
0.8LiCl-0.2SrCl2	0.678498	1.290164	2.426133
0.9LiCl-0.1SrCl2	0.744127	1.340994	2.431240
0.7LiCl-0.3SrCl2	0.608142	1.228236	2.417277
0.7LiCl-0.3MnCl2	0.646595	1.258369	2.522866
0.9LiCl-0.1BeCl2	0.647482	1.270125	2.382546
0.6LiCl-0.4SrCl2	0.533471	1.150233	2.403564
0.9LiCl-0.1CoCl2	0.740452	1.315419	2.415763
0.8LiCl-0.2BeCl2	0.515301	1.148937	2.326905
0.8LiCl-0.2CoCl2	0.672763	1.242254	2.390288
0.6LiCl-0.4MnCl2	0.565076	1.163548	2.542041
0.5LiCl-0.5SrCl2	0.453400	1.053096	2.382739
0.7LiCl-0.3BeCl2	0.405345	1.022003	2.263917
0.7LiCl-0.3CoCl2	0.601046	1.156646	2.361118
0.1LiCl-0.9PbCl2	0.135418	0.501826	2.556433
0.9LiCl-0.1MgCl2	0.700983	1.295298	2.384859
0.6LiCl-0.4CoCl2	0.524219	1.059036	2.324670
0.9LiCl-0.1NaCl	0.665132	1.303963	2.426739
0.4LiCl-0.6SrCl2	0.367630	0.930443	2.351609
0.5LiCl-0.5MnCl2	0.479109	1.046886	2.555894
0.6LiCl-0.4BeCl2	0.313972	0.887559	2.192593
0.9LiCl-0.1CaCl2	0.727618	1.292920	2.377266
0.5LiCl-0.5CoCl2	0.443516	0.945340	2.280200
0.8LiCl-0.2MgCl2	0.600852	1.198624	2.328728
0.5LiCl-0.5BeCl2	0.237600	0.747647	2.113751
0.8LiCl-0.2NaCl	0.557680	1.217905	2.413427
0.9LiCl-0.1KCl	0.731148	1.257260	2.316839

Figure 31 and Table 8 show the ratio of tritium production to ^{36}Cl production for each ternary salt. As with the binary salts, the general trend highlights the inverse relationship between tritium production and ^{36}Cl production. The variance between salts is lower for ternary salts, but salts containing $MnCl_2$ remain outliers with low ^{36}Cl production.

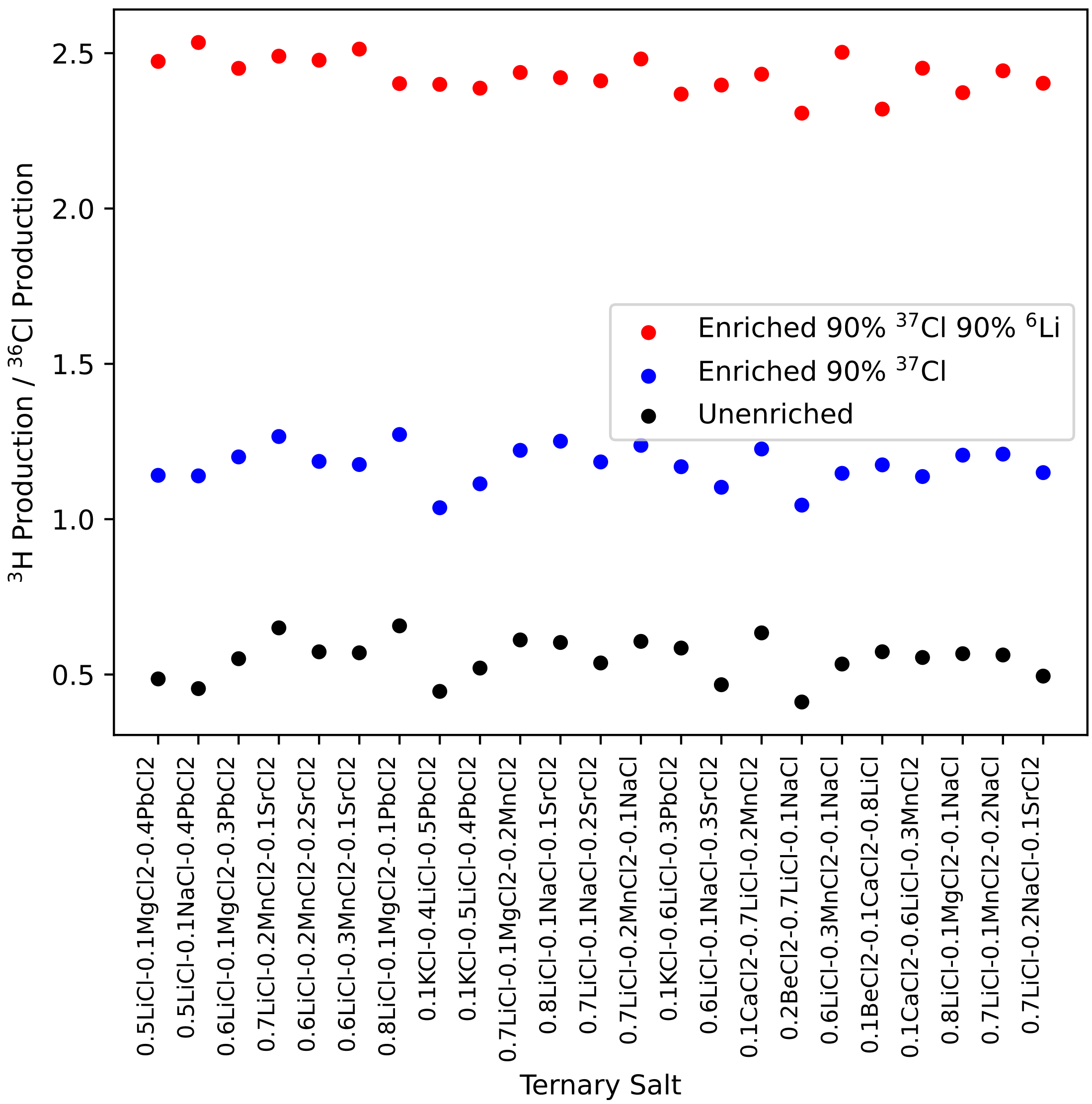


Figure 31. The ternary salts' tritium production to ^{36}Cl production ratio.

Table 8. The ratio of ^{3}H production to ^{36}Cl production in each salt.

Salt	Unenriched	90% Enriched ^{37}Cl	90% Enriched ^{6}Li-^{37}Cl
0.5LiCl-0.1MgCl2-0.4PbCl2	0.485823	1.141073	2.473478
0.5LiCl-0.1NaCl-0.4PbCl2	0.454620	1.139370	2.534379
0.6LiCl-0.1MgCl2-0.3PbCl2	0.550870	1.200424	2.451147
0.7LiCl-0.2MnCl2-0.1SrCl2	0.650140	1.266036	2.490297
0.6LiCl-0.2MnCl2-0.2SrCl2	0.573030	1.185987	2.477379
0.6LiCl-0.3MnCl2-0.1SrCl2	0.569816	1.175902	2.513146
0.8LiCl-0.1MgCl2-0.1PbCl2	0.656641	1.272470	2.402058
0.1KCl-0.4LiCl-0.5PbCl2	0.445673	1.036800	2.399569
0.1KCl-0.5LiCl-0.4PbCl2	0.520736	1.113811	2.387374
0.7LiCl-0.1MgCl2-0.2MnCl2	0.611238	1.221547	2.437838
0.8LiCl-0.1NaCl-0.1SrCl2	0.603108	1.250991	2.421130
0.7LiCl-0.1NaCl-0.2SrCl2	0.537148	1.184290	2.411039
0.7LiCl-0.2MnCl2-0.1NaCl	0.606649	1.237668	2.481336
0.1KCl-0.6LiCl-0.3PbCl2	0.585146	1.168873	2.368288
0.6LiCl-0.1NaCl-0.3SrCl2	0.467141	1.102678	2.397287
0.1CaCl2-0.7LiCl-0.2MnCl2	0.633961	1.225936	2.432326
0.2BeCl2-0.7LiCl-0.1NaCl	0.411465	1.045194	2.306919
0.6LiCl-0.3MnCl2-0.1NaCl	0.533727	1.147504	2.502823
0.1BeCl2-0.1CaCl2-0.8LiCl	0.573191	1.174813	2.319967
0.1CaCl2-0.6LiCl-0.3MnCl2	0.554794	1.137256	2.451604
0.8LiCl-0.1MgCl2-0.1NaCl	0.566953	1.206032	2.372878
0.7LiCl-0.1MnCl2-0.2NaCl	0.562845	1.209443	2.443261
0.7LiCl-0.2NaCl-0.1SrCl2	0.494873	1.149845	2.403111

3.5 HIGH-COST NEUTRONICS SIMULATIONS

The approach to defining the high-cost neutronics filter can be found in Section 2.4.3. Figure 32 shows the tritium breeding ratio for a subset of salts, including the ARC composition of FLiBe. The ARC FLiBe TBR (1.127) is very similar to the baseline FLiBe composition, with ^{6}Li enriched to 90% TBR (1.128) used as a benchmark in the low- and medium-cost neutron filters.

The first row presents the TBR within the inner salt channel. The second row shows the TBR within the blanket. The tritium breeding ratio within the channel is higher for FLiBe than in the chloride salts. This channel is approximately 3 cm thick. However, the TBR within the blanket is higher for all five chloride salts enriched to 90% in both ^{37}Cl and ^{6}Li. Future work should explore the optimization of thicker blanket tanks designed for the increased neutron mean free path that exists when using chloride salts. Summing these two regions yielded the identification that all the selected chloride salts enriched to 90% in both ^{37}Cl and ^{6}Li produced more tritium than FLiBe.

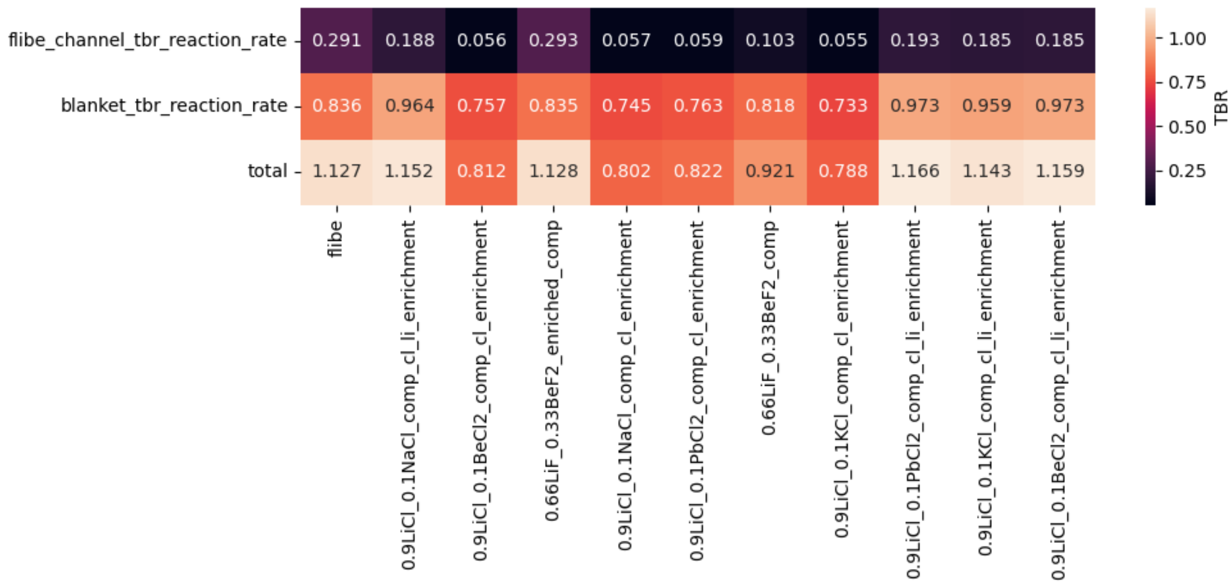


Figure 32. The FERMI TBR output for a subset of binary chloride salt compositions.

3.6 COMPARISON OF NEUTRONICS SIMULATIONS

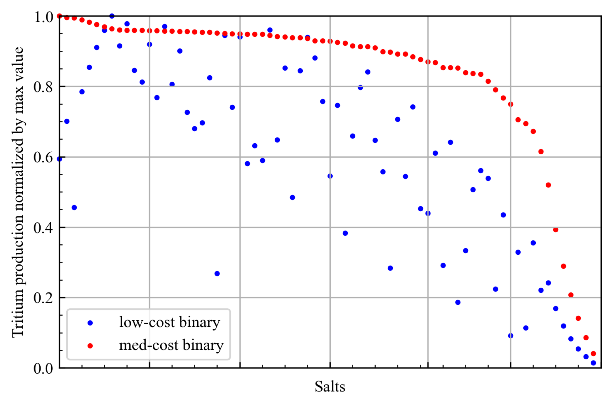
Because of the large number of plausible chloride salt mixtures, it was important to begin the study with a low-cost filter to reduce the domain size. The computational cost of estimating a singular salt's tritium production potential using the low-, medium-, and high-cost filters required roughly 0.5×10^{-4}, 25, and 50 CPU hours, respectively. This significant range of computational cost highlights the value of reduced-order methods for scoping large domains.

3.6.1 Low-Cost versus Medium-Cost Neutronics

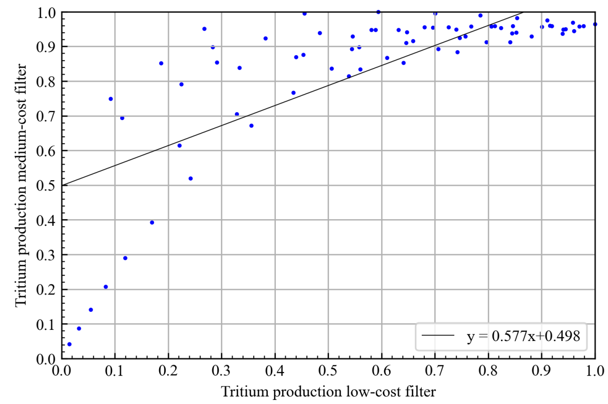
Figure 33a presents the binary salt tritium production of the low- and medium-cost filters, each normalized by the respective series's maximum value. Data were sorted in descending order of the medium-cost filter. A linear regression and correlation scatter plot of the binary salt comparison between the two filters is shown in Figure 33b. An R^2 value of 0.55 indicates that 55% of the variability can be explained by the regression. Figure 33c presents the ternary salt tritium production of the low- and medium-cost filters, each normalized by the respective series's maximum value. Data were sorted in descending order of the medium-cost filter. A linear regression and correlation scatter plot of the ternary salt comparison between the two filters is shown in Figure 33d. An R^2 value of 0.75 indicates that 75% of the variability can be explained by the regression. For both binary and ternary data sets, the low-cost approach generally predicted lower values for tritium production. This behavior was expected and was discussed in Section 2.4.1, where Equation 10 highlights the extension of the FOM to include neutron-multiplying cross sections.

3.6.2 Medium-Cost versus High-Cost Neutronics

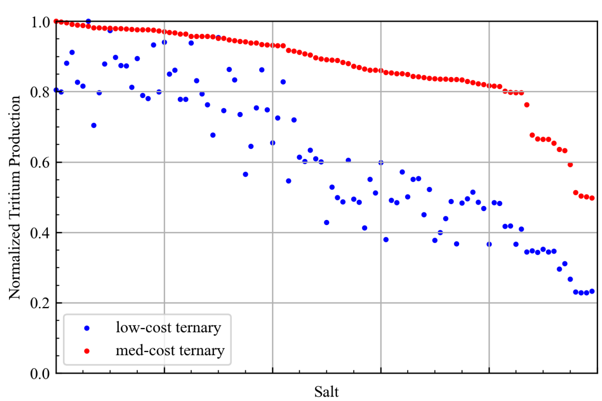
Both medium- and high-cost neutronics simulations predicted that there are chloride salt compositions capable of higher tritium production than FLiBe. Also, for the four compositions investigated under the high-cost approach, both medium- and high-cost tritium production trends were identical.



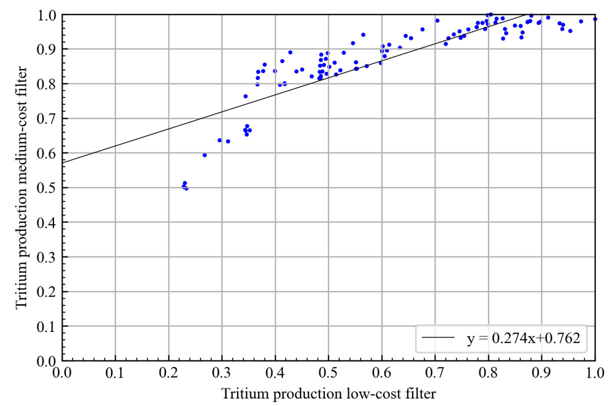
(a) Tritium production of the binary salts.



(b) Correlated behavior of the binary salts.



(c) Tritium production of the ternary salts.



(d) Correlated behavior of the ternary salts.

Figure 33. Tritium production predictions and correlated behavior between the low- and medium-cost neutronics filters.

3.7 HEAT TRANSFER AND FLUID FLOW CONSIDERATIONS

After the low-, medium-, and high-cost neutronics investigations, the effort was focused on applying more thermophysical filters to continue determining the most promising salts. Up until this time, minimal consideration had been made regarding the viscosity, thermal conductivity, and specific heat capacity. The process outlined by Williams et al. [39] regarding molten salt coolant heat transfer and fluid flow comparisons for an advanced high-temperature reactor was applied here for the fusion liquid breeder blanket.

The process recommends comparing the heat transfer and fluid flow performance of candidate coolants to other coolants that humans have more experience with. Appendix D lists the thermophysical properties of candidate chloride salts at 600°C, along with values for FLiBe at 600°C and water at 300°C and 15.5 MPa [2,250 psi] for a comparison with pressurized water reactor (PWR) coolant. The calculation requires that the specific heat capacity be expressed per unit mass (such as $\frac{J}{g-K}$) and not per unit mole (such as $\frac{J}{mol-K}$).

Bonilla [40] defined a turbulent forced convection flow FOM with an objective to minimize pumping power for a constant coolant temperature rise dependent only on the dynamics viscosity, μ; density, ρ; and specific heat capacity, c_p, as

$$FOM_{flow} = \frac{\mu^{0.2}}{\rho^2 c_p^{2.8}} \tag{11}$$

Sanders [41] proposed a heat transfer FOM with an objective to compare heat exchanger coolants. This FOM is only relevant when comparing heat transfer fluids within small ranges of property values. For example, comparing the relative performance between molten salt and liquid metal coolants was not recommended.

$$FOM_{heat} = \frac{\mu^{0.2}}{c_p^{0.4} k^{0.6} \rho^{0.3}} \tag{12}$$

Table 9 summarizes the two FOMs normalized by values for FLiBe. In each case, a lower score is desirable. The table demonstrates that H_2O_{PWR} is superior to FLiBe and all chloride molten salts for flow and heat transfer FOMs. FLiBe also receives a better score than all chloride molten salts. The turbulent forced convection flow FOM shows a large range of scores for chloride salts with various LiCl-NaCl compositions repeatedly scoring near the top of the list and was followed by $CaCl_2$-, $MgCl_2$-, and KCl-bearing salts. The LiCl-NaCl also scored consistently at the top for the heat transfer FOM and was also followed by $CaCl_2$-, $MgCl_2$-, and KCl-bearing salts.

Notably, high LiCl mass fractions did well relative to low LiCl mass fraction in the tritium production metrics, the turbulent flow FOM, and the heat transfer FOM. This discovery is yet another justification for high LiCl mass fractions in a chloride fusion liquid breeder blanket.

Unfortunately, TP data are lacking for LiCl-$PbCl_2$, which was the best tritium-producing chloride salt from the low-, medium-, and high-cost neutronic studies. Data were also unavailable for $MnCl_2$, $CoCl_2$, and all ternary salt compositions.

Table 9. Performance of binary chloride salts quantified by turbulent forced convection flow and heat transfer FOMs normalized by values for FLiBe. Water at 300°C and 15.5 MPa [2,250 psi] is also provided for a comparison with pressurized water reactor coolant.

Turbulent forced convection		**Heat exchanger area**	
Coolant	$\frac{FOM_{flow,i}}{FOM_{flow,FLiBe}}$	**Coolant**	$\frac{FOM_{heat,i}}{FOM_{heat,FLiBe}}$
H_2O_{PWR}	0.27	H_2O_{PWR}	0.59
66LiF-33BeF_2[mol %]	1.00	66LiF-33BeF_2[mol %]	1.00
0.9LiCl-0.1NaCl	4.64	0.9LiCl-0.1NaCl	1.32
0.9LiCl-0.1$CaCl_2$	4.81	0.8LiCl-0.2NaCl	1.34
0.8LiCl-0.2NaCl	4.84	0.9LiCl-0.1KCl	1.34
0.9LiCl-0.1$MgCl_2$	4.84	0.9LiCl-0.1$MgCl_2$	1.35
0.9LiCl-0.1KCl	4.86	0.9LiCl-0.1$CaCl_2$	1.36
0.7LiCl-0.3NaCl	5.05	0.7LiCl-0.3NaCl	1.36
0.8LiCl-0.2$CaCl_2$	5.21	0.8LiCl-0.2KCl	1.38
0.6LiCl-0.4NaCl	5.28	0.6LiCl-0.4NaCl	1.38
0.8LiCl-0.2$MgCl_2$	5.29	0.5LiCl-0.5NaCl	1.40
0.8LiCl-0.2KCl	5.33	0.9LiCl-0.1$BeCl_2$	1.40
0.5LiCl-0.5NaCl	5.53	0.9LiCl-0.1$SrCl_2$	1.41
0.9LiCl-0.1$SrCl_2$	5.65	0.8LiCl-0.2$MgCl_2$	1.41

Table 9. Performance of binary chloride salts quantified by turbulent forced convection flow and heat transfer FOMs normalized by values for FLiBe. Water at 300°C and 15.5 MPa [2,250 psi] is also provided for a comparison with pressurized water reactor coolant.

Turbulent forced convection		Heat exchanger area	
Coolant	$\frac{FOM_{flow,i}}{FOM_{flow,FLiBe}}$	**Coolant**	$\frac{FOM_{heat,i}}{FOM_{heat,FLiBe}}$
0.7LiCl-0.3$CaCl_2$	5.67	0.8LiCl-0.2$CaCl_2$	1.41
0.4LiCl-0.6NaCl	5.80	0.7LiCl-0.3KCl	1.42
0.7LiCl-0.3$MgCl_2$	5.81	0.4LiCl-0.6NaCl	1.42
0.7LiCl-0.3KCl	5.87	0.3LiCl-0.7NaCl	1.45
0.9LiCl-0.1$BeCl_2$	6.08	0.6LiCl-0.4KCl	1.47
0.3LiCl-0.7NaCl	6.09	0.7LiCl-0.3$CaCl_2$	1.47
0.6LiCl-0.4$CaCl_2$	6.20	0.2LiCl-0.8NaCl	1.48
0.6LiCl-0.4$MgCl_2$	6.41	0.7LiCl-0.3$MgCl_2$	1.48
0.2LiCl-0.8NaCl	6.41	0.1LiCl-0.9NaCl	1.51
0.6LiCl-0.4KCl	6.49	0.8LiCl-0.2$SrCl_2$	1.52
0.1LiCl-0.9NaCl	6.76	0.5LiCl-0.5KCl	1.52
0.5LiCl-0.5$CaCl_2$	6.81	0.8LiCl-0.2$BeCl_2$	1.53
0.5LiCl-0.5$MgCl_2$	7.11	0.6LiCl-0.4$CaCl_2$	1.54
0.5LiCl-0.5KCl	7.21	0.9LiCl-0.1$AlCl_3$	1.56
0.8LiCl-0.2$SrCl_2$	7.37	0.6LiCl-0.4$MgCl_2$	1.56
0.4LiCl-0.6$CaCl_2$	7.51	0.4LiCl-0.6KCl	1.59
0.4LiCl-0.6$MgCl_2$	7.95	0.5LiCl-0.5$CaCl_2$	1.62
0.4LiCl-0.6KCl	8.06	0.7LiCl-0.3$SrCl_2$	1.66
0.8LiCl-0.2$BeCl_2$	8.60	0.5LiCl-0.5$MgCl_2$	1.67
0.3LiCl-0.7KCl	9.07	0.3LiCl-0.7KCl	1.67
0.7LiCl-0.3$SrCl_2$	9.99	0.7LiCl-0.3$BeCl_2$	1.69
0.2LiCl-0.8KCl	10.28	0.4LiCl-0.6$CaCl_2$	1.71
0.7LiCl-0.3$BeCl_2$	12.69	0.2LiCl-0.8KCl	1.76
0.9LiCl-0.1$AlCl_3$	13.64	0.8LiCl-0.2$AlCl_3$	1.79
0.6LiCl-0.4$SrCl_2$	14.24	0.4LiCl-0.6$MgCl_2$	1.80
0.6LiCl-0.4$BeCl_2$	19.83	0.6LiCl-0.4$SrCl_2$	1.82
0.5LiCl-0.5$SrCl_2$	21.82	0.6LiCl-0.4$BeCl_2$	1.90
0.8LiCl-0.2$AlCl_3$	29.71	0.7LiCl-0.3$AlCl_3$	2.00
0.5LiCl-0.5$BeCl_2$	33.45	0.5LiCl-0.5$SrCl_2$	2.03
0.4LiCl-0.6$SrCl_2$	37.21	0.5LiCl-0.5$BeCl_2$	2.18
0.7LiCl-0.3$AlCl_3$	54.92	0.6LiCl-0.4$AlCl_3$	2.22
0.4LiCl-0.6$BeCl_2$	63.21	0.4LiCl-0.6$SrCl_2$	2.30
0.6LiCl-0.4$AlCl_3$	91.73	0.5LiCl-0.5$AlCl_3$	2.46
0.3LiCl-0.7$BeCl_2$	142.89	0.4LiCl-0.6$BeCl_2$	2.61
0.5LiCl-0.5$AlCl_3$	144.45	0.4LiCl-0.6$AlCl_3$	2.74
0.4LiCl-0.6$AlCl_3$	215.73	0.3LiCl-0.7$AlCl_3$	3.11
0.3LiCl-0.7$AlCl_3$	312.11	0.3LiCl-0.7$BeCl_2$	3.32
0.2LiCl-0.8$AlCl_3$	433.09	0.2LiCl-0.8$AlCl_3$	3.65
0.2LiCl-0.8$BeCl_2$	447.73	0.2LiCl-0.8$BeCl_2$	4.72

Table 9. Performance of binary chloride salts quantified by turbulent forced convection flow and heat transfer FOMs normalized by values for FLiBe. Water at 300°C and 15.5 MPa [2,250 psi] is also provided for a comparison with pressurized water reactor coolant.

Turbulent forced convection		Heat exchanger area	
Coolant	$\frac{FOM_{flow,i}}{FOM_{flow,FLiBe}}$	**Coolant**	$\frac{FOM_{heat,i}}{FOM_{heat,FLiBe}}$
$0.1LiCl\text{-}0.9AlCl_3$	566.76	$0.1LiCl\text{-}0.9AlCl_3$	4.80
$0.1LiCl\text{-}0.9BeCl_2$	3,131.30	$0.1LiCl\text{-}0.9BeCl_2$	8.86
$0.3LiCl\text{-}0.7PbCl_2$	N/A	$0.3LiCl\text{-}0.7PbCl_2$	N/A
$0.4LiCl\text{-}0.6PbCl_2$	N/A	$0.4LiCl\text{-}0.6PbCl_2$	N/A
$0.2LiCl\text{-}0.8PbCl_2$	N/A	$0.2LiCl\text{-}0.8PbCl_2$	N/A
$0.5LiCl\text{-}0.5PbCl_2$	N/A	$0.5LiCl\text{-}0.5PbCl_2$	N/A
$0.6LiCl\text{-}0.4PbCl_2$	N/A	$0.6LiCl\text{-}0.4PbCl_2$	N/A
$0.7LiCl\text{-}0.3PbCl_2$	N/A	$0.7LiCl\text{-}0.3PbCl_2$	N/A
$0.8LiCl\text{-}0.2PbCl_2$	N/A	$0.8LiCl\text{-}0.2PbCl_2$	N/A
$0.9LiCl\text{-}0.1PbCl_2$	N/A	$0.9LiCl\text{-}0.1PbCl_2$	N/A
$0.7LiCl\text{-}0.3MnCl_2$	N/A	$0.7LiCl\text{-}0.3MnCl_2$	N/A
$0.9LiCl\text{-}0.1CoCl_2$	N/A	$0.9LiCl\text{-}0.1CoCl_2$	N/A
$0.8LiCl\text{-}0.2CoCl_2$	N/A	$0.8LiCl\text{-}0.2CoCl_2$	N/A
$0.6LiCl\text{-}0.4MnCl_2$	N/A	$0.6LiCl\text{-}0.4MnCl_2$	N/A
$0.7LiCl\text{-}0.3CoCl_2$	N/A	$0.7LiCl\text{-}0.3CoCl_2$	N/A
$0.1LiCl\text{-}0.9PbCl_2$	N/A	$0.1LiCl\text{-}0.9PbCl_2$	N/A
$0.6LiCl\text{-}0.4CoCl_2$	N/A	$0.6LiCl\text{-}0.4CoCl_2$	N/A
$0.5LiCl\text{-}0.5MnCl_2$	N/A	$0.5LiCl\text{-}0.5MnCl_2$	N/A
$0.5LiCl\text{-}0.5CoCl_2$	N/A	$0.5LiCl\text{-}0.5CoCl_2$	N/A
$0.4LiCl\text{-}0.6CoCl_2$	N/A	$0.4LiCl\text{-}0.6CoCl_2$	N/A
$0.2LiCl\text{-}0.8MnCl_2$	N/A	$0.2LiCl\text{-}0.8MnCl_2$	N/A

3.8 DISCUSSION OF MOST-PROMISING SALTS

3.8.1 Binary Salts

The following section focuses on the positives and negatives of the top tritium-producing binary salts and discusses them in order from most to least productive. Thermochemical considerations, such as vapor pressure, redox potential, and more, of the most promising salts still need to be made in further detail. For non-alkali and non-alkaline earth chloride salts, more than one possible ion states exist. This possibility makes salt chemistry analysis significantly more complex than for alkali and alkaline earth salts.

The $LiCl\text{-}PbCl_2$ produced the most tritium of any binary salt at all mass fractions except for $0.1LiCl\text{-}0.9PbCl_2$. The $0.3LiCl\text{-}0.7PbCl_2$ composition was the tritium production leader with a liquidus temperature of 697 K [424°C]. The $0.4LiCl\text{-}0.6PbCl_2$ composition was predicted to produce 0.4% less tritium than $0.3LiCl\text{-}0.7PbCl_2$ but with the advantage of the lowest Pb-containing liquidus temperature of 667 K [394°C]. The element Pb is not listed in the short- or midterm US Department of Energy (DOE) critical materials report [42]. The toxicity and high structural costs owing to the high fluid density are negatives. An apparent negative of the LiCl-$PbCl_2$ system is the generation of $PbCl_4$ through radiolysis, which has a boiling temperature of 50°C and would result in a high vapor pressure [2]. This is the result of having an undesirably high number of ionization state. At this time, no viscosity, thermal conductivity, or specific heat capacity measurement data exist within the MSTDB-TP for LiCl-$PbCl_2$ salts. Therefore, LiCl-$PbCl_2$ could not be evaluated by FOM_{flow} and FOM_{heat}.

The LiCl-$SrCl_2$ was the second-most tritium-producing chloride salt with many mass fractions near the top of the list. The best performing composition was the 0.8LiCl-0.2$SrCl_2$ liquidus temperature of 816 K [543°C]. The 0.6LiCl-0.4$SrCl_2$ composition was predicted to produce 0.2% less tritium than 0.8LiCl-0.2$SrCl_2$ but with the advantage of a 29°C lower liquidus temperature at 787 K [514°C]. The element Sr is listed in the DOE critical materials report [42] but with a low risk. The LiCl-$SrCl_2$ thermophysical data were available for this salt, and the primary outliers are that this salt has a slightly higher viscosity and lower specific heat capacity than the other chloride salts. A double neutron capture pathway also exists to create ^{90}Sr from stable ^{88}Sr, which is 83% naturally abundant. The medium-cost neutronic filter did not observe any production of the ^{90}Sr isotope. However, notably, the isotope has a 28.9 year half-life, emits a 0.55 MeV β particle, and the human body has the propensity to transport Sr like Ca and places it into the bones. The element Sr also has multiple ionization states, which complicates the blanket chemistry. The LiCl-SrCl received adequate scores for both FOM_{flow} and FOM_{heat}.

The LiCl-$MnCl_2$ produced 4% less tritium than the leading Pb-containing salt with the 0.7LiCl-0.3$MnCl_2$ composition. The liquidus temperature for this mass fraction was 852 K [580°C]. Adjusting the mass fraction to find a lower liquidus temperature while minimally affecting the tritium production yielded no significant gain. The element Mn is listed in the DOE critical materials report [42] but with low- to medium-term risks. Safety data sheets warn of category 3 acute oral toxicity [43]. Being a transition metal, Mn has the possibility to exist in multiple ionization states. Blanket chemistry could be complicated by this fact and radiolysis. The Mn in structural alloys is typically attacked and corroded by molten salts such as Cr. Production of ^{54}Mn should be investigated further because of its 312 day half-life and high observed activity in the medium-cost neutronics simulations. At this time, no viscosity, thermal conductivity, or specific heat capacity measurement data exist within the MSTDB-TP for LiCl-$MnCl_2$ salts. Therefore, LiCl-$MnCl_2$ could not be evaluated by FOM_{flow} and FOM_{heat}.

The LiCl-$BeCl_2$ was another top performer with near-equal tritium production as those of LiCl-$SrCl_2$ and LiCl-$MnCl_2$. The most-producing mass fraction was 0.9LiCl-0.1$BeCl_2$, with a liquidus temperature of 849 K [577°C]. This temperature can be significantly decreased by several hundred degrees but with significant decreases in tritium production. A 0.1LiCl-0.9$BeCl_2$ composition melts at 451 K [178°C]. The element Be is not listed in the short- or midterm DOE critical materials report [42]. Unfortunately, Be has unique health hazards and associated challenges working with it. Also, one of the primary goals of investigating alternatives to FLiBe was to determine if molten salts without Be could act as efficient liquid breeder blankets. The element Be is an alkaline earth metal and has a single ionization state, which simplifies the salt system. The LiCl-$BeCl_2$ thermophysical data were available for this salt, and the primary outliers are that this salt has a slightly higher viscosity and lower specific heat capacity than the other chloride salts. The LiCl-$SrCl_2$ received adequate scores for FOM_{flow} and FOM_{heat}.

The LiCl-$CoCl_2$ has good tritium production potential, but it has significant drawbacks in the categories of liquidus temperature, price, toxicity, and activation of ^{60}Co, which has a 5.27 year half-life and a high-energy gamma decay. Safety data sheets warn of category 4 acute oral toxicity [43]. The element Co also has multiple ionization states, which complicates the blanket chemistry. Co is listed in both the short- and medium-term DOE critical materials report [42] as having critical status to the importance to energy and supply risk. The redox potential diagrams of [44] suggest that $CoCl_2$ may be a challenge considering its potential is less negative than typical structural alloys such as Fe, Cr, Ti, and Al. At this time, no viscosity, thermal conductivity, or specific heat capacity measurement data exist within the MSTDB-TP for LiCl-$CoCl_2$ salts. Therefore, LiCl-$CoCl_2$ could not be evaluated by FOM_{flow} and FOM_{heat}.

The LiCl-$MgCl_2$ was found to surpass 66LiF-33BeF_2 tritium production but only at 80% and 90% Li mass fractions. This narrower band of compositions limits optimizing other TP and TC parameters. In this band, the liquidus temperature ranged from 800 to 847 K [527°C–574°C]. The element Mg is listed as a short-term, near-critical element and increases to critical to the importance to energy and supply risk in the medium-term [42]. Safety data sheets do not considered $MgCl_2$ hazardous [43]. Residing in the alkaline earth group, a single ionization state exists for the salt system. An important technology overlap exists with $MgCl_2$; it is used in the halide slagging step of the pyrometallurgical process. However, research into $MgCl_2$ chloride salts has shown that multiple hydroxides can form, which are difficult to purify and remove. The LiCl-$MgCl_2$ received good scores for FOM_{flow} and FOM_{heat}.

The LiCl-NaCl was able to surpass FLiBe tritium production at only 0.9LiCl-0.1NaCl and 0.8LiCl-0.2NaCl compositions. In this band, the liquidus temperature ranged from 808 to 848 K [535°C–574°C]. The compound NaCl has the advantages of being abundant, of low cost, and has a low health risk relative to other candidate salts. The element Na is listed in the DOE critical materials report [42] but with a low risk. Safety data sheets do not consider $MgCl_2$ hazardous [43]. Residing in the alkali group, a single ionization state simplifies the salt system. The redox potential diagrams of [44] suggest that NaCl salts have a very negative value. The LiCl-NaCl received good scores for FOM_{flow} and FOM_{heat}.

The LiCl-$CaCl_2$ was able to surpass FLiBe tritium production at only the 0.9LiCl-0.1$CaCl_2$ composition with a liquidus temperature of 848 K [575°C]. The element Ca is not listed in the DOE critical materials report [42]. Residing in the alkaline earth group, a single ionization state simplifies the salt system. An important technology overlap exists with $CaCl_2$; it is used in the halide slagging step of the pyrometallurgical process. Residing in the alkaline earth group similar to $MgCl_2$, perhaps the potential also exists to form multiple hydroxides that are difficult to purify and remove. The production of ^{41}Ca occurs through the $^{40}Ca(n,\gamma)^{41}Ca$ reaction with a 100,000 year half-life [2]. The LiCl-$CaCl_2$ received good scores for FOM_{flow} and FOM_{heat}.

The LiCl-KCl was able to surpass FLiBe tritium production at only the 0.9LiCl-0.1$CaCl_2$ composition with a liquidus temperature of 797 K [523°C]. The element K is not listed in the DOE critical materials report [42]. The compound KCl has the advantages of being abundant, of low cost, and has a low health risk relative to other candidate salts. Safety data sheets do not consider KCl hazardous [43]. Residing in the alkali group, a single ionization state simplifies the salt system. The redox potential diagrams of [44] suggest that KCl salts have a very negative value. An important technology overlap exists with KCl; it is used in the electrorefining step of the pyrometallurgical process. There is the possibility for ^{36}Cl production through the $^{39}K(n,\alpha)^{36}Cl$ reaction, albeit with relatively small yield [2]. The LiCl-KCl received good scores for FOM_{flow} and FOM_{heat}.

Table 10 provides a scoring summary of the top binary salts under consideration. A weight was subjectively assigned to each category. A grading scale between 1 and 5 was used to score each binary salt for each category, with 5 being good or desirable relative to chloride salts. Two summations of scores were then taken. The first total sums the first seven columns of the table, neglecting FOM_{flow} and FOM_{heat} owing to a lack of TP data to evaluate. The second sum in square brackets includes these two FOM columns. The highest-scoring salt neglecting fluid and heat transfer FOMs was LiCl-NaCl, followed closely by LiCl-$PbCl_2$, LiCl-$MgCl_2$, and LiCl-$SrCl_2$. When considering the additional FOMs, LiCl-NaCl remains at the top,

$LiCl$-$PbCl_2$ does not get evaluated owing to a lack of data, and $LiCl$-$MgCl_2$ extends its lead on $LiCl$-$SrCl_2$ with more favorable flow and heat transfer scores. Appendix D presents the performance and data availability of the most promising binary salts sorted by tritium production in descending order evaluated at 873 K [600°C].

Based on these binary elemental configurations, the following mass fraction recommendations can be made:

- 0.9LiCl-0.1NaCl is needed to maximize tritium production.
- 0.3LiCl-0.7$PbCl_2$ maximizes tritium production, but 0.4LiCl-0.6$PbCl_2$ does nearly as well with a 30°C lower liquidus temperature.
- 0.9LiCl-0.1$MgCl_2$ maximizes tritium production, but 0.8LiCl-0.2$MgCl_2$ may be attractive with a 50°C lower liquidus temperature.
- 0.8LiCl-0.2$SrCl_2$ maximizes tritium production, but 0.7LiCl-0.3$PbCl_2$ does nearly as well with a 32°C lower liquidus temperature.

Table 10. Scoring table of most promising binary chloride salts ordered by tritium production. A score of 5 represents excellent performance of that salt in that category relative to all chloride salts. Summation of total scores neglecting and [including] FOM_{flow} and FOM_{heat} owing to a lack of TP data to evaluate.

Salt	^3H	Liquidus	Price	Toxic	Ionic	Redox	Activate	FOM_{flow}	FOM_{heat}	Total
Weight	5	2	1	1	2	2	1	1	1	
$LiCl$-$PbCl_2$	5	5	3	2	3	2	5	N/A	N/A	55 [00]
$LiCl$-$SrCl_2$	4	4	4	3	5	2	4	4	4	53 [61]
$LiCl$-$MnCl_2$	4	2	4	3	3	2	2	N/A	N/A	43 [00]
$LiCl$-$BeCl_2$	4	4	1	1	4	5	5	4	4	53 [61]
$LiCl$-$CoCl_2$	4	2	2	2	3	2	3	N/A	N/A	41 [00]
$LiCl$-$MgCl_2$	3	3	5	5	4	5	5	5	5	54 [64]
LiCl-NaCl	3	3	5	5	5	5	5	5	5	56 [66]
$LiCl$-$CaCl_2$	3	3	3	4	4	5	4	5	5	50 [60]
LiCl-KCl	2	3	4	5	5	5	5	5	5	50 [60]

3.8.2 Ternary Salts

From the low- and medium-cost neutronic analyses, binary salts outperformed ternary salts. TP and TC motivations often exist to create ternary molten salts, such as the NaCl-KCl-$MgCl_2$ salt selected by the DOE Solar Energy Technologies Office for the Generation 3 Concentrating Solar Power Systems liquid pathway [37].

As for the thousands of neutronically investigated ternary chloride salts, the only lithiated entries in the MSTDB-TP are for LiCl-NaCl-KCl and LiCl-NaCl-$AlCl_3$. This limited data availability highlights the need for extensive TP property generation of ternary chloride salts if they are to be systematically studied in further detail. Appendix E presents the performance and data availability of the most-promising binary salts, sorted by tritium production in descending order and evaluated at 873 K [600°C]. The $PbCl_2$- and $SrCl_2$-containing ternary salts were consistently at the top of the list.

Using Table 10 and Appendix E as guides, the following mass fraction recommendations can be made:

- 0.5LiCl-0.1$MgCl_2$-0.4$PbCl_2$ produced the most tritium and had one of the lowest liquidus temperatures at 678 K [405°C].
- 0.7LiCl-0.2$MnCl_2$-0.1$SrCl_2$ and 0.6LiCl-0.2$MnCl_2$-0.2$SrCl_2$ performed near the top without the use of $PbCl_2$.
- 0.8LiCl-0.1$MgCl_2$-0.1NaCl was the highest tritium-producing salt containing NaCl and $MgCl_2$.

4. CONCLUSIONS AND RECOMMENDATIONS

The hypothesis proposed at the beginning of the research was that there could be chloride-based blanket designs that can nearly equal or exceed the TBR)s of FLiBe molten salt blankets. The fastest and most cost-effective path to deploying liquid fusion breeder blankets could be from maximizing the synergistic technological overlap between fusion, fission, concentrated solar, and thermal energy storage industries. The approach to addressing this hypothesis consisted of applying a multilevel serial filtering process to systematically downselect the most promising chloride-based salts to optimize economic, neutronic, TP, and TC parameters.

4.1 CONCLUSIONS

As observed in Table 2, a total of 79 unary salts were initially identified. This search resulted in 3,081 binary, 79,079 ternary, and 1,502,501 quaternary permutations of plausible chloride salts. The first step in reducing the domain was applying economic filters for commercial availability and a price threshold of $1,000/kg. This filter reduced the number of plausible unary salts from 79 to 30. The low-cost neutronics filter reinforced engineering judgement for the requirement of Li-bearing salts. A TC filter of salt liquidus temperature less than 873 K [600°C] further reduced the domain to 12 unary salts. A 1D medium-cost neutronics filter determined 10 unary salts in 9 binary and 10 ternary permutations with tritum breeding potentials greater than FLiBe. Finally, a 3D high-cost neutronics filter investigated four binary salt compositions and confirmed the findings of the medium-cost neutronics results.

Table 10 provides a scoring summary of the top binary salts under consideration. A weight was subjectively assigned to each category. The highest-scoring salt neglecting fluid and heat transfer FOMs was LiCl-NaCl, followed closely by LiCl-$PbCl_2$, LiCl-$MgCl_2$, and LiCl-$SrCl_2$. When considering the additional FOMs, LiCl-NaCl remains at the top, LiCl-$PbCl_2$ did not get evaluated owing to a lack of data, and LiCl-$MgCl_2$ extends its lead on LiCl-$SrCl_2$ with more favorable flow and heat transfer scores. Appendix D presents the performance and data availability of the most-promising binary salts, sorted by tritium production in descending order and evaluated at 873 K [600°C].

Highlights of chloride salt performance relative to FLiBe include the following:

1. Several compositions were found with higher-than-FLiBe tritium production potential.
2. Higher-than-FLiBe tritium production was achieved without optimizing blanket dimensions for chloride salts.
3. The liquidus temperature distribution of chlorides with more tritium production than FLiBe ranges ±100°C around that of FLiBe. Ternary chloride salts have a 30°C lower average liquidus temperature than the binary chloride salts.

4. Commercial-scale pricing is difficult to estimate. Recent small-batch FLiBe salt procurements at ORNL have cost between $1,000 and $2,000/kg. Given the $1,000/kg price filter used on chloride salts, all prospective chlorides are less expensive and are heavily driven by the 80%–90% LiCl mass fraction at approximately $360/kg.
5. Chloride salts have been identified with higher-than-FLiBe tritium production without the use of Be or Pb.
6. Some candidate chloride salts have the ability to exist in multiple ionization states, which complicates blanket chemistry.
7. Activation results suggest that chloride salts have larger decay heat values than FLiBe.
8. FOM for fluid flow and heat transfer define chloride salts as less desirable than FLiBe owing primarily to lower specific heat capacities.
9. An important technology overlap exists with $MgCl_2$ and $CaCl_2$; they are already used in the halide slagging step of the pyrometallurgical process. Also, the binary salt LiCl-KCl is used in the electrorefining step of the pyrometallurgical process, so significant operational experience and TP and TC properties exist.

4.2 CANDIDATE SALTS

Section 3.8 provides a detailed discussion on candidate binary and ternary salt selection. The most promising binary chloride salts were LiCl-$PbCl_2$, LiCl-$SrCl_2$, LiCl-$MnCl_2$, LiCl-$BeCl_2$, LiCl-$CoCl_2$, LiCl-$MgCl_2$, LiCl-NaCl, LiCl-$CaCl_2$, and LiCl-KCl. Based on these binary configurations, the following mass fraction recommendations can be made:

- 0.9LiCl-0.1NaCl is needed to maximize tritium production.
- 0.3LiCl-0.7$PbCl_2$ maximizes tritium production, but 0.4LiCl-0.6$PbCl_2$ does nearly as well with a 30°C lower liquidus temperature.
- 0.9LiCl-0.1$MgCl_2$ maximizes tritium production, but 0.8LiCl-0.2$MgCl_2$ may be attractive with a 50°C lower liquidus temperature.
- 0.8LiCl-0.2$SrCl_2$ maximizes tritium production, but 0.7LiCl-0.3$PbCl_2$ does nearly as well with a 32°C lower liquidus temperature.
- 0.5LiCl-0.1$MgCl_2$-0.4$PbCl_2$ produced the most tritium of any ternary salt and had one of the lowest liquidus temperatures at 678 K [405°C].
- 0.7LiCl-0.2$MnCl_2$-0.1$SrCl_2$ and 0.6LiCl-0.2$MnCl_2$-0.2$SrCl_2$ performed near the top of ternary salts without the use of $PbCl_2$.
- 0.8LiCl-0.1$MgCl_2$-0.1NaCl was the highest tritium-producing salt containing NaCl and $MgCl_2$.

4.3 DATA NEEDS

While performing this research, it became apparent that the state of the TP and TC properties databases were dense in some areas and sparse in others. Williams et al. provides an overview of the accuracy and uncertainty of measuring and predicting these quantities [39].

For the binary chloride salts highlighted in Section 3.4, 75% of the density values were determined through the MSTDB-TP either via experimental measurement or RK expansion. The remaining 25% were estimated using the ideal mixing theory. Also, from the MSTDB-TP, 75% of viscosity, thermal conductivity, and specific heat capacity values could be determined. Table 5. in Appendix D summarizes the TP data availability of the most promising binary salts sorted by tritium production in descending order. The ternary salt TP data are particularly sparse; see Appendix E.

TP data need to exist for unary salts $PbCl_2$, $MnCl_2$, and $SrCl_2$. Experimental TP and TC binary and ternary measurements containing LiCl-NaCl, LiCl-$PbCl_2$, LiCl-$MgCl_2$, and LiCl-$SrCl_2$ salts should be of the highest priority for progressing the technology readiness level of chloride salt fusion liquid breeder blankets.

4.4 FUTURE WORK

Future work includes focusing on the following areas of development:

1. Expand the MSTDB-TP and MSTDB-TC with experimental measurements and RK parameter formulation.
2. Optimize a magnetically confined fusion reactor geometry within the 3D FERMI framework based on the neutronic, TP, and TC requirements of the most-promising chloride salts.
3. Apply a low-pass activation filter using the methodology defined by Fetter et al. [45] which expands beyond 10CFR61 by defining specific activity limits (activation densities) for fusion-relevant isotopes. The activity vs. time data was generated in this effort, but it needs to be processed and applied as a threshold to eliminate high-activation salt compositions.
4. Build chloride salt–containing capsules and perform neutron irradiation experiments at the Spallation Neutron Source (SNS), a high-performance research reactor, or a prototypic fusion source facility to validate numerical predictions of tritium production.
5. Build a lab-scale forced convective flow loop designed to circulate the most-promising chloride salt using operational experience gained from the Liquid Salt Test Loop (LSTL) and FASTR molten salt flow loops [36; 38].
6. Couple the lab-scale flow loop to a neutron source, such as a beamline similar to SNS, a high-performance research reactor, or a prototypic fusion source facility, to demonstrate tritium breeding at the system level, reduce cost, and reduce risk of future pilot- and commercial-scale plants.
7. Integrate lessons learned through this systematic and iterative methodology to aid designing the US Fusion Pilot Plant so that fusion can be brought to the US grid with an efficient chloride salt liquid breeder blanket [1].

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APPENDIX A. UNARY SALT PRICE ARRAY

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Salt	Size [kg]	Price [$]	Unit price [$ /kg]	Purity [%]
AgCl	0.1	408	4,080	99
$AlCl_3$	0.5	124	248	99
$AsCl_3$	0.1	509	5,090	99.9
$BaCl_2$	0.25	449	1,796	99.9
$BeCl_2$	1	33600	33,600	99
$BiCl_3$	0.1	327	3,270	98
$CaCl_2$	0.5	183	366	97
$CdCl_2$	0.5	369	738	99
$CeCl_3$	0.25	994	3,976	99.5
$CoCl_2$	0.5	370	740	97
$CrCl_2$	0.025	556	22,240	95
$CrCl_3$	0.25	285	1,140	98
CsCl	0.25	259	1,036	99
CuCl	0.5	61.4	122.8	97
$CuCl_2$	0.25	75.8	303.2	97
$DyCl_3$	0.025	1010	40,400	99.9
$ErCl_3$	0.05	339	6,780	99.9
$EuCl_3$	0.01	492	49,200	99.9
$FeCl_2$	0.25	783	3,132	98
$FeCl_3$	0.5	64	128	97
$Ga2Cl_4$	0.005	231	46,200	99.9
$GaCl_3$	0.1	543	5,430	99.9
$GdCl_3$	0.025	772	30,880	99.9
$GeCl_4$	0.025	336	13,440	99.9
$HfCl_4$	0.1	222	2,220	98
$Hg2Cl_2$	0.1	71.9	719	99.5
$HgCl_2$	0.5	227	454	98
$HoCl_3$	0.025	491	19,640	99.9
ICl	0.5	305	610	99
$InCl_3$	0.025	180	7,200	98
KCl	0.5	74.8	149.6	99
$LaCl_3$	0.1	488	4,880	99.9
LiCl	0.5	178	356	99
$LuCl_3$	0.005	633	126,600	99.9
$MgCl_2$	1	64.9	64.9	99
$MnCl_2$	0.5	49.1	98.2	97
$MoCl_3$	0.01	231	23,100	99.5
$MoCl_5$	0.25	551	2,204	99.6
NaCl	1	66.2	66.2	99
$NbCl_5$	0.05	177	3,540	99
$NdCl_3$	0.025	1100	44,000	99.9
Nh_4Cl	0.5	60.5	121	99.5

Salt	Size [kg]	Price [$]	Unit price [$ /kg]	Purity [%]
$NiCl_2$	0.25	230	920	98
$PbCl_2$	0.25	91.2	364.8	98
PCl_3	0.25	75.2	300.8	98
PCl_5	0.1	47.2	472	98
$PrCl_3$	0.005	215	43,000	99.9
$PtCl_2$	0.005	809	161,800	98
RbCl	0.1	499	4,990	99
$ReCl_3$	0.001	481	481,000	99.9
$RhCl_3$	0.002	1360	680,000	99.5
$RuCl_3$	0.01	518	51,800	99
$SbCl_3$	0.5	141	282	99
$SbCl_5$	0.25	111	444	99
$ScCl_3$	0.005	1170	234,000	99.9
SeCl	0.025	406	16,240	99
$SeCl_4$	0.1	393	3,930	99.5
$SiCl_4$	0.1	30	300	99
$SmCl_3$	0.01	128	12,800	99.9
$SnCl_2$	0.5	242	484	98
$SnCl_4$	0.25	77.9	311.6	98
$SrCl_2$	0.5	68.6	137.2	95
$TaCl_5$	0.1	505	5,050	99.8
$TbCl_3$	0.005	302	60,400	99.9
$TeCl_4$	0.1	371	3,710	99.9
$TiCl_4$	0.1	215	2,150	99.9
TlCl	0.025	132	5,280	99
VCl_3	0.05	443	8,860	99
WCl_6	0.25	855	3,420	99
$YbCl_3$	0.25	167	668	99.9
YCl_3	0.05	298	5,960	99.9
$ZnCl_2$	0.5	32.6	65.2	98
$ZrCl_4$	0.5	266	532	99.5

APPENDIX B. BINARY SALT TRITIUM PRODUCTION

APPENDIX B. BINARY SALT TRITIUM PRODUCTION

Table 12. Binary salt tritium production normalized to unenriched FLiBe tritium production.

Salt	Unenriched	90% Enriched ^{37}Cl	90% Enriched ^{6}Li-^{37}Cl
0.1LiCl-0.9AlCl3	0.010580	0.010250	0.049070
0.2LiCl-0.8AlCl3	0.023340	0.022690	0.103390
0.3LiCl-0.7AlCl3	0.039570	0.038510	0.168240
0.4LiCl-0.6AlCl3	0.060840	0.059390	0.247610
0.5LiCl-0.5AlCl3	0.089750	0.087980	0.345680
0.6LiCl-0.4AlCl3	0.130800	0.129150	0.468580
0.7LiCl-0.3AlCl3	0.192810	0.192160	0.620140
0.8LiCl-0.2AlCl3	0.292050	0.296200	0.801730
0.9LiCl-0.1AlCl3	0.461190	0.482910	0.995440
0.7LiCl-0.3BaCl2	0.706800	0.793160	1.164250
0.8LiCl-0.2BaCl2	0.756260	0.857380	1.166900
0.9LiCl-0.1BaCl2	0.798600	0.913090	1.167100
0.1LiCl-0.9BeCl2	0.170740	0.253980	0.893720
0.2LiCl-0.8BeCl2	0.304540	0.439570	1.016230
0.3LiCl-0.7BeCl2	0.412040	0.561590	1.071410
0.4LiCl-0.6BeCl2	0.497130	0.641190	1.101370
0.5LiCl-0.5BeCl2	0.563890	0.696140	1.119690
0.6LiCl-0.4BeCl2	0.616790	0.736590	1.130990
0.7LiCl-0.3BeCl2	0.658350	0.767190	1.138170
0.8LiCl-0.2BeCl2	0.691180	0.790580	1.141990
0.9LiCl-0.1BeCl2	0.717170	0.808750	1.143550
0.4LiCl-0.6CaCl2	0.455090	0.515710	0.998250
0.5LiCl-0.5CaCl2	0.519020	0.584470	1.035260
0.6LiCl-0.4CaCl2	0.573550	0.644000	1.064790
0.7LiCl-0.3CaCl2	0.621580	0.696660	1.088780
0.8LiCl-0.2CaCl2	0.664290	0.742520	1.108900
0.9LiCl-0.1CaCl2	0.702610	0.784920	1.127440
0.4LiCl-0.6CoCl2	0.498010	0.561190	1.108180
0.5LiCl-0.5CoCl2	0.558650	0.629720	1.123210
0.6LiCl-0.4CoCl2	0.607730	0.685270	1.132060
0.7LiCl-0.3CoCl2	0.648210	0.730620	1.137710
0.8LiCl-0.2CoCl2	0.682080	0.767970	1.140750
0.9LiCl-0.1CoCl2	0.710730	0.798600	1.142380
0.2LiCl-0.8KCl	0.215340	0.235990	0.733100
0.3LiCl-0.7KCl	0.303640	0.330390	0.841030
0.4LiCl-0.6KCl	0.383550	0.416970	0.915420
0.5LiCl-0.5KCl	0.455800	0.497310	0.971930
0.6LiCl-0.4KCl	0.521890	0.571910	1.017590
0.7LiCl-0.3KCl	0.582890	0.641360	1.054590

Continued on next page

Table 12. Binary salt tritium production normalized to unenriched FLiBe tritium production.

Salt	Unenriched	90% Enriched ^{37}Cl	90% Enriched ^{6}Li-^{37}Cl
0.8LiCl-0.2KCl	0.638540	0.705870	1.088620
0.9LiCl-0.1KCl	0.689810	0.766290	1.117250
0.6LiCl-0.4LaCl3	0.646980	0.723360	1.150030
0.7LiCl-0.3LaCl3	0.676550	0.755620	1.150570
0.8LiCl-0.2LaCl3	0.700090	0.782010	1.148700
0.9LiCl-0.1LaCl3	0.720240	0.803900	1.146580
0.4LiCl-0.6MgCl2	0.486250	0.571970	1.045100
0.5LiCl-0.5MgCl2	0.547630	0.634240	1.071790
0.6LiCl-0.4MgCl2	0.598810	0.686430	1.092160
0.7LiCl-0.3MgCl2	0.642650	0.729910	1.108340
0.8LiCl-0.2MgCl2	0.679590	0.767640	1.121980
0.9LiCl-0.1MgCl2	0.711450	0.799000	1.133730
0.2LiCl-0.8MnCl2	0.282820	0.330460	1.018190
0.5LiCl-0.5MnCl2	0.536310	0.619980	1.131120
0.6LiCl-0.4MnCl2	0.594190	0.684680	1.139910
0.7LiCl-0.3MnCl2	0.642550	0.737950	1.143870
0.1LiCl-0.9NaCl	0.189230	0.262330	0.827880
0.2LiCl-0.8NaCl	0.326700	0.431410	0.943440
0.3LiCl-0.7NaCl	0.427940	0.539260	1.000400
0.4LiCl-0.6NaCl	0.504950	0.614540	1.037590
0.5LiCl-0.5NaCl	0.565270	0.672090	1.064720
0.6LiCl-0.4NaCl	0.613980	0.716610	1.085810
0.7LiCl-0.3NaCl	0.654410	0.754010	1.103340
0.8LiCl-0.2NaCl	0.688060	0.783950	1.118880
0.9LiCl-0.1NaCl	0.716030	0.808120	1.132010
0.1LiCl-0.9PbCl2	0.403020	0.479630	1.135330
0.2LiCl-0.8PbCl2	0.561350	0.647530	1.187070
0.3LiCl-0.7PbCl2	0.637000	0.725320	1.192990
0.4LiCl-0.6PbCl2	0.677810	0.767230	1.187720
0.5LiCl-0.5PbCl2	0.701960	0.790810	1.180160
0.6LiCl-0.4PbCl2	0.716700	0.805900	1.172120
0.7LiCl-0.3PbCl2	0.726210	0.814370	1.164320
0.8LiCl-0.2PbCl2	0.731770	0.819290	1.156400
0.9LiCl-0.1PbCl2	0.735230	0.821190	1.150120
0.4LiCl-0.6SrCl2	0.578960	0.665480	1.131130
0.5LiCl-0.5SrCl2	0.626820	0.714900	1.139610
0.6LiCl-0.4SrCl2	0.662340	0.751050	1.143090
0.7LiCl-0.3SrCl2	0.689710	0.778240	1.144480
0.8LiCl-0.2SrCl2	0.710040	0.798010	1.145620
0.9LiCl-0.1SrCl2	0.725640	0.812660	1.144580

Table 13. Binary salt tritium production normalized to 30% ^{6}Li enriched FLiBe tritium production.

Salt	Unenriched	90% Enriched ^{37}Cl	90% Enriched ^{6}Li-^{37}Cl
0.1LiCl-0.9AlCl3	0.009640	0.009340	0.044700
0.2LiCl-0.8AlCl3	0.021260	0.020670	0.094200
0.3LiCl-0.7AlCl3	0.036050	0.035090	0.153270
0.4LiCl-0.6AlCl3	0.055420	0.054100	0.225580
0.5LiCl-0.5AlCl3	0.081770	0.080150	0.314930
0.6LiCl-0.4AlCl3	0.119170	0.117660	0.426890
0.7LiCl-0.3AlCl3	0.175650	0.175060	0.564970
0.8LiCl-0.2AlCl3	0.266070	0.269850	0.730400
0.9LiCl-0.1AlCl3	0.420160	0.439950	0.906870
0.7LiCl-0.3BaCl2	0.643910	0.722590	1.060660
0.8LiCl-0.2BaCl2	0.688970	0.781100	1.063080
0.9LiCl-0.1BaCl2	0.727540	0.831840	1.063260
0.1LiCl-0.9BeCl2	0.155540	0.231380	0.814210
0.2LiCl-0.8BeCl2	0.277450	0.400460	0.925810
0.3LiCl-0.7BeCl2	0.375380	0.511630	0.976080
0.4LiCl-0.6BeCl2	0.452900	0.584140	1.003380
0.5LiCl-0.5BeCl2	0.513720	0.634200	1.020070
0.6LiCl-0.4BeCl2	0.561910	0.671050	1.030360
0.7LiCl-0.3BeCl2	0.599780	0.698930	1.036900
0.8LiCl-0.2BeCl2	0.629680	0.720240	1.040380
0.9LiCl-0.1BeCl2	0.653360	0.736790	1.041800
0.4LiCl-0.6CaCl2	0.414600	0.469820	0.909430
0.5LiCl-0.5CaCl2	0.472840	0.532470	0.943150
0.6LiCl-0.4CaCl2	0.522520	0.586700	0.970060
0.7LiCl-0.3CaCl2	0.566270	0.634670	0.991910
0.8LiCl-0.2CaCl2	0.605190	0.676450	1.010240
0.9LiCl-0.1CaCl2	0.640100	0.715080	1.027130
0.4LiCl-0.6CoCl2	0.453700	0.511260	1.009580
0.5LiCl-0.5CoCl2	0.508950	0.573700	1.023270
0.6LiCl-0.4CoCl2	0.553660	0.624300	1.031330
0.7LiCl-0.3CoCl2	0.590540	0.665620	1.036480
0.8LiCl-0.2CoCl2	0.621390	0.699640	1.039250
0.9LiCl-0.1CoCl2	0.647500	0.727550	1.040740
0.2LiCl-0.8KCl	0.196180	0.214990	0.667880
0.3LiCl-0.7KCl	0.276620	0.300990	0.766200
0.4LiCl-0.6KCl	0.349420	0.379870	0.833980
0.5LiCl-0.5KCl	0.415240	0.453060	0.885450
0.6LiCl-0.4KCl	0.475460	0.521030	0.927050
0.7LiCl-0.3KCl	0.531030	0.584290	0.960760
0.8LiCl-0.2KCl	0.581730	0.643070	0.991760

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Table 13. Binary salt tritium production normalized to 30% ^{6}Li enriched FLiBe tritium production.

Salt	Unenriched	90% Enriched ^{37}Cl	90% Enriched ^{6}Li-^{37}Cl
0.9LiCl-0.1KCl	0.628430	0.698110	1.017840
0.6LiCl-0.4LaCl3	0.589420	0.659000	1.047710
0.7LiCl-0.3LaCl3	0.616360	0.688390	1.048200
0.8LiCl-0.2LaCl3	0.637800	0.712430	1.046500
0.9LiCl-0.1LaCl3	0.656160	0.732370	1.044560
0.4LiCl-0.6MgCl2	0.442990	0.521080	0.952110
0.5LiCl-0.5MgCl2	0.498900	0.577810	0.976430
0.6LiCl-0.4MgCl2	0.545530	0.625360	0.994990
0.7LiCl-0.3MgCl2	0.585470	0.664960	1.009730
0.8LiCl-0.2MgCl2	0.619120	0.699340	1.022160
0.9LiCl-0.1MgCl2	0.648150	0.727910	1.032860
0.2LiCl-0.8MnCl2	0.257660	0.301060	0.927600
0.5LiCl-0.5MnCl2	0.488590	0.564820	1.030480
0.6LiCl-0.4MnCl2	0.541320	0.623760	1.038490
0.7LiCl-0.3MnCl2	0.585380	0.672290	1.042100
0.1LiCl-0.9NaCl	0.172400	0.238990	0.754220
0.2LiCl-0.8NaCl	0.297630	0.393030	0.859500
0.3LiCl-0.7NaCl	0.389870	0.491280	0.911390
0.4LiCl-0.6NaCl	0.460020	0.559860	0.945280
0.5LiCl-0.5NaCl	0.514980	0.612290	0.969980
0.6LiCl-0.4NaCl	0.559350	0.652850	0.989200
0.7LiCl-0.3NaCl	0.596180	0.686920	1.005170
0.8LiCl-0.2NaCl	0.626840	0.714200	1.019330
0.9LiCl-0.1NaCl	0.652320	0.736220	1.031290
0.1LiCl-0.9PbCl2	0.367160	0.436950	1.034320
0.2LiCl-0.8PbCl2	0.511400	0.589920	1.081460
0.3LiCl-0.7PbCl2	0.580320	0.660790	1.086840
0.4LiCl-0.6PbCl2	0.617500	0.698970	1.082040
0.5LiCl-0.5PbCl2	0.639510	0.720450	1.075150
0.6LiCl-0.4PbCl2	0.652930	0.734190	1.067840
0.7LiCl-0.3PbCl2	0.661600	0.741920	1.060720
0.8LiCl-0.2PbCl2	0.666660	0.746400	1.053510
0.9LiCl-0.1PbCl2	0.669810	0.748120	1.047790
0.4LiCl-0.6SrCl2	0.527450	0.606270	1.030490
0.5LiCl-0.5SrCl2	0.571050	0.651290	1.038210
0.6LiCl-0.4SrCl2	0.603410	0.684230	1.041390
0.7LiCl-0.3SrCl2	0.628340	0.709000	1.042650
0.8LiCl-0.2SrCl2	0.646870	0.727010	1.043690
0.9LiCl-0.1SrCl2	0.661080	0.740350	1.042740

Table 14. Binary salt tritium production normalized to 60% ^{6}Li enriched FLiBe tritium production.

Salt	Unenriched	90% Enriched ^{37}Cl	90% Enriched ^{6}Li-^{37}Cl
0.1LiCl-0.9AlCl3	0.009470	0.009170	0.043900
0.2LiCl-0.8AlCl3	0.020880	0.020300	0.092510
0.3LiCl-0.7AlCl3	0.035410	0.034460	0.150530
0.4LiCl-0.6AlCl3	0.054430	0.053140	0.221550
0.5LiCl-0.5AlCl3	0.080310	0.078720	0.309300
0.6LiCl-0.4AlCl3	0.117040	0.115550	0.419260
0.7LiCl-0.3AlCl3	0.172510	0.171930	0.554870
0.8LiCl-0.2AlCl3	0.261320	0.265030	0.717350
0.9LiCl-0.1AlCl3	0.412650	0.432090	0.890670
0.7LiCl-0.3BaCl2	0.632410	0.709680	1.041710
0.8LiCl-0.2BaCl2	0.676660	0.767140	1.044090
0.9LiCl-0.1BaCl2	0.714550	0.816980	1.044260
0.1LiCl-0.9BeCl2	0.152770	0.227250	0.799660
0.2LiCl-0.8BeCl2	0.272490	0.393300	0.909270
0.3LiCl-0.7BeCl2	0.368680	0.502490	0.958640
0.4LiCl-0.6BeCl2	0.444810	0.573710	0.985450
0.5LiCl-0.5BeCl2	0.504540	0.622870	1.001840
0.6LiCl-0.4BeCl2	0.551870	0.659060	1.011950
0.7LiCl-0.3BeCl2	0.589060	0.686450	1.018380
0.8LiCl-0.2BeCl2	0.618430	0.707370	1.021800
0.9LiCl-0.1BeCl2	0.641690	0.723630	1.023190
0.4LiCl-0.6CaCl2	0.407190	0.461430	0.893180
0.5LiCl-0.5CaCl2	0.464390	0.522950	0.926300
0.6LiCl-0.4CaCl2	0.513180	0.576220	0.952720
0.7LiCl-0.3CaCl2	0.556160	0.623330	0.974190
0.8LiCl-0.2CaCl2	0.594370	0.664370	0.992190
0.9LiCl-0.1CaCl2	0.628660	0.702310	1.008780
0.4LiCl-0.6CoCl2	0.445590	0.502120	0.991550
0.5LiCl-0.5CoCl2	0.499860	0.563450	1.004990
0.6LiCl-0.4CoCl2	0.543770	0.613150	1.012910
0.7LiCl-0.3CoCl2	0.579990	0.653730	1.017970
0.8LiCl-0.2CoCl2	0.610290	0.687140	1.020690
0.9LiCl-0.1CoCl2	0.635930	0.714550	1.022140
0.2LiCl-0.8KCl	0.192680	0.211150	0.655950
0.3LiCl-0.7KCl	0.271680	0.295610	0.752510
0.4LiCl-0.6KCl	0.343180	0.373090	0.819080
0.5LiCl-0.5KCl	0.407820	0.444960	0.869630
0.6LiCl-0.4KCl	0.466970	0.511720	0.910480
0.7LiCl-0.3KCl	0.521540	0.573850	0.943600
0.8LiCl-0.2KCl	0.571330	0.631580	0.974040

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Table 14. Binary salt tritium production normalized to 60% ^{6}Li enriched FLiBe tritium production.

Salt	Unenriched	90% Enriched ^{37}Cl	90% Enriched ^{6}Li-^{37}Cl
0.9LiCl-0.1KCl	0.617210	0.685640	0.999660
0.6LiCl-0.4LaCl3	0.578890	0.647230	1.028990
0.7LiCl-0.3LaCl3	0.605350	0.676090	1.029480
0.8LiCl-0.2LaCl3	0.626400	0.699700	1.027800
0.9LiCl-0.1LaCl3	0.644430	0.719290	1.025900
0.4LiCl-0.6MgCl2	0.435070	0.511770	0.935100
0.5LiCl-0.5MgCl2	0.489990	0.567480	0.958980
0.6LiCl-0.4MgCl2	0.535780	0.614180	0.977210
0.7LiCl-0.3MgCl2	0.575010	0.653080	0.991690
0.8LiCl-0.2MgCl2	0.608060	0.686850	1.003900
0.9LiCl-0.1MgCl2	0.636570	0.714900	1.014410
0.2LiCl-0.8MnCl2	0.253060	0.295680	0.911030
0.5LiCl-0.5MnCl2	0.479860	0.554730	1.012070
0.6LiCl-0.4MnCl2	0.531650	0.612620	1.019930
0.7LiCl-0.3MnCl2	0.574920	0.660280	1.023480
0.1LiCl-0.9NaCl	0.169320	0.234720	0.740740
0.2LiCl-0.8NaCl	0.292310	0.386010	0.844140
0.3LiCl-0.7NaCl	0.382900	0.482500	0.895110
0.4LiCl-0.6NaCl	0.451800	0.549860	0.928390
0.5LiCl-0.5NaCl	0.505780	0.601350	0.952650
0.6LiCl-0.4NaCl	0.549360	0.641190	0.971530
0.7LiCl-0.3NaCl	0.585530	0.674650	0.987210
0.8LiCl-0.2NaCl	0.615640	0.701440	1.001120
0.9LiCl-0.1NaCl	0.640660	0.723060	1.012860
0.1LiCl-0.9PbCl2	0.360600	0.429150	1.015840
0.2LiCl-0.8PbCl2	0.502270	0.579380	1.062130
0.3LiCl-0.7PbCl2	0.569950	0.648980	1.067430
0.4LiCl-0.6PbCl2	0.606470	0.686480	1.062710
0.5LiCl-0.5PbCl2	0.628080	0.707580	1.055940
0.6LiCl-0.4PbCl2	0.641270	0.721080	1.048760
0.7LiCl-0.3PbCl2	0.649780	0.728660	1.041770
0.8LiCl-0.2PbCl2	0.654750	0.733060	1.034690
0.9LiCl-0.1PbCl2	0.657850	0.734760	1.029070
0.4LiCl-0.6SrCl2	0.518030	0.595440	1.012080
0.5LiCl-0.5SrCl2	0.560850	0.639660	1.019670
0.6LiCl-0.4SrCl2	0.592630	0.672000	1.022780
0.7LiCl-0.3SrCl2	0.617110	0.696330	1.024020
0.8LiCl-0.2SrCl2	0.635310	0.714020	1.025040
0.9LiCl-0.1SrCl2	0.649270	0.727120	1.024110

Table 15. Binary salt tritium production normalized to 90% ^{6}Li enriched FLiBe tritium production.

Salt	Unenriched	90% Enriched ^{37}Cl	90% Enriched ^{6}Li-^{37}Cl
0.1LiCl-0.9AlCl3	0.009500	0.009210	0.044080
0.2LiCl-0.8AlCl3	0.020970	0.020380	0.092880
0.3LiCl-0.7AlCl3	0.035550	0.034600	0.151130
0.4LiCl-0.6AlCl3	0.054650	0.053350	0.222430
0.5LiCl-0.5AlCl3	0.080630	0.079030	0.310530
0.6LiCl-0.4AlCl3	0.117500	0.116010	0.420930
0.7LiCl-0.3AlCl3	0.173200	0.172610	0.557080
0.8LiCl-0.2AlCl3	0.262350	0.266080	0.720200
0.9LiCl-0.1AlCl3	0.414290	0.433800	0.894210
0.7LiCl-0.3BaCl2	0.634920	0.712500	1.045850
0.8LiCl-0.2BaCl2	0.679350	0.770190	1.048240
0.9LiCl-0.1BaCl2	0.717390	0.820230	1.048410
0.1LiCl-0.9BeCl2	0.153370	0.228150	0.802840
0.2LiCl-0.8BeCl2	0.273570	0.394870	0.912890
0.3LiCl-0.7BeCl2	0.370140	0.504480	0.962450
0.4LiCl-0.6BeCl2	0.446580	0.575990	0.989370
0.5LiCl-0.5BeCl2	0.506550	0.625350	1.005820
0.6LiCl-0.4BeCl2	0.554070	0.661680	1.015970
0.7LiCl-0.3BeCl2	0.591400	0.689170	1.022420
0.8LiCl-0.2BeCl2	0.620890	0.710180	1.025860
0.9LiCl-0.1BeCl2	0.644240	0.726500	1.027260
0.4LiCl-0.6CaCl2	0.408810	0.463260	0.896730
0.5LiCl-0.5CaCl2	0.466240	0.525030	0.929980
0.6LiCl-0.4CaCl2	0.515220	0.578510	0.956510
0.7LiCl-0.3CaCl2	0.558370	0.625810	0.978060
0.8LiCl-0.2CaCl2	0.596740	0.667010	0.996130
0.9LiCl-0.1CaCl2	0.631160	0.705100	1.012790
0.4LiCl-0.6CoCl2	0.447360	0.504120	0.995490
0.5LiCl-0.5CoCl2	0.501840	0.565690	1.008980
0.6LiCl-0.4CoCl2	0.545930	0.615580	1.016930
0.7LiCl-0.3CoCl2	0.582290	0.656320	1.022010
0.8LiCl-0.2CoCl2	0.612710	0.689870	1.024740
0.9LiCl-0.1CoCl2	0.638460	0.717390	1.026210
0.2LiCl-0.8KCl	0.193440	0.211990	0.658550
0.3LiCl-0.7KCl	0.272760	0.296790	0.755500
0.4LiCl-0.6KCl	0.344540	0.374570	0.822330
0.5LiCl-0.5KCl	0.409440	0.446730	0.873090
0.6LiCl-0.4KCl	0.468820	0.513750	0.914100
0.7LiCl-0.3KCl	0.523620	0.576130	0.947350
0.8LiCl-0.2KCl	0.573600	0.634090	0.977910

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Table 15. Binary salt tritium production normalized to 90% ^{6}Li enriched FLiBe tritium production.

Salt	Unenriched	90% Enriched ^{37}Cl	90% Enriched ^{6}Li-^{37}Cl
0.9LiCl-0.1KCl	0.619660	0.688370	1.003630
0.6LiCl-0.4LaCl3	0.581190	0.649800	1.033080
0.7LiCl-0.3LaCl3	0.607750	0.678780	1.033570
0.8LiCl-0.2LaCl3	0.628890	0.702490	1.031890
0.9LiCl-0.1LaCl3	0.646990	0.722150	1.029980
0.4LiCl-0.6MgCl2	0.436800	0.513800	0.938820
0.5LiCl-0.5MgCl2	0.491930	0.569740	0.962790
0.6LiCl-0.4MgCl2	0.537910	0.616620	0.981100
0.7LiCl-0.3MgCl2	0.577290	0.655680	0.995630
0.8LiCl-0.2MgCl2	0.610480	0.689580	1.007880
0.9LiCl-0.1MgCl2	0.639100	0.717740	1.018440
0.2LiCl-0.8MnCl2	0.254060	0.296860	0.914650
0.5LiCl-0.5MnCl2	0.481770	0.556940	1.016090
0.6LiCl-0.4MnCl2	0.533760	0.615050	1.023990
0.7LiCl-0.3MnCl2	0.577200	0.662910	1.027550
0.1LiCl-0.9NaCl	0.169990	0.235650	0.743690
0.2LiCl-0.8NaCl	0.293480	0.387540	0.847490
0.3LiCl-0.7NaCl	0.384420	0.484420	0.898670
0.4LiCl-0.6NaCl	0.453600	0.552050	0.932080
0.5LiCl-0.5NaCl	0.507790	0.603740	0.956440
0.6LiCl-0.4NaCl	0.551540	0.643740	0.975390
0.7LiCl-0.3NaCl	0.587860	0.677330	0.991140
0.8LiCl-0.2NaCl	0.618090	0.704230	1.005100
0.9LiCl-0.1NaCl	0.643210	0.725940	1.016890
0.1LiCl-0.9PbCl2	0.362030	0.430850	1.019880
0.2LiCl-0.8PbCl2	0.504260	0.581680	1.066360
0.3LiCl-0.7PbCl2	0.572220	0.651560	1.071670
0.4LiCl-0.6PbCl2	0.608880	0.689210	1.066930
0.5LiCl-0.5PbCl2	0.630580	0.710390	1.060140
0.6LiCl-0.4PbCl2	0.643820	0.723940	1.052930
0.7LiCl-0.3PbCl2	0.652360	0.731560	1.045910
0.8LiCl-0.2PbCl2	0.657350	0.735970	1.038800
0.9LiCl-0.1PbCl2	0.660460	0.737680	1.033160
0.4LiCl-0.6SrCl2	0.520090	0.597810	1.016100
0.5LiCl-0.5SrCl2	0.563080	0.642200	1.023720
0.6LiCl-0.4SrCl2	0.594980	0.674670	1.026850
0.7LiCl-0.3SrCl2	0.619570	0.699100	1.028090
0.8LiCl-0.2SrCl2	0.637840	0.716860	1.029120
0.9LiCl-0.1SrCl2	0.651850	0.730010	1.028180

Table 16. The binary salt ^{36}Cl production (atoms/b-cm).

Salt	Unenriched	90% Enriched ^{37}Cl	90% Enriched ^{6}Li-^{37}Cl
0.3LiCl-0.7PbCl2	9.5330e-04	3.9492e-04	2.5450e-04
0.4LiCl-0.6PbCl2	8.1398e-04	3.7427e-04	2.5706e-04
0.2LiCl-0.8PbCl2	1.1932e-03	4.3629e-04	2.5204e-04
0.5LiCl-0.5PbCl2	7.2404e-04	3.6191e-04	2.5938e-04
0.6LiCl-0.4PbCl2	6.6044e-04	3.5437e-04	2.6173e-04
0.7LiCl-0.3PbCl2	6.1270e-04	3.4878e-04	2.6361e-04
0.8LiCl-0.2PbCl2	5.7610e-04	3.4517e-04	2.6529e-04
0.9LiCl-0.1PbCl2	5.4648e-04	3.4224e-04	2.6680e-04
0.8LiCl-0.2SrCl2	5.9695e-04	3.5283e-04	2.6935e-04
0.9LiCl-0.1SrCl2	5.5626e-04	3.4568e-04	2.6855e-04
0.7LiCl-0.3SrCl2	6.4693e-04	3.6144e-04	2.7007e-04
0.7LiCl-0.3MnCl2	5.6685e-04	3.3452e-04	2.5863e-04
0.9LiCl-0.1BeCl2	6.3182e-04	3.6322e-04	2.7379e-04
0.6LiCl-0.4SrCl2	7.0822e-04	3.7246e-04	2.7128e-04
0.9LiCl-0.1CoCl2	5.4753e-04	3.4631e-04	2.6975e-04
0.8LiCl-0.2BeCl2	7.6512e-04	3.9251e-04	2.7995e-04
0.8LiCl-0.2CoCl2	5.7832e-04	3.5264e-04	2.7223e-04
0.6LiCl-0.4MnCl2	5.9981e-04	3.3566e-04	2.5579e-04
0.5LiCl-0.5SrCl2	7.8861e-04	3.8724e-04	2.7282e-04
0.7LiCl-0.3BeCl2	9.2647e-04	4.2821e-04	2.8678e-04
0.7LiCl-0.3CoCl2	6.1519e-04	3.6032e-04	2.7486e-04
0.1LiCl-0.9PbCl2	1.6976e-03	5.4519e-04	2.5333e-04
0.9LiCl-0.1MgCl2	5.7894e-04	3.5186e-04	2.7117e-04
0.6LiCl-0.4CoCl2	6.6130e-04	3.6910e-04	2.7778e-04
0.9LiCl-0.1NaCl	6.1407e-04	3.5352e-04	2.6609e-04
0.4LiCl-0.6SrCl2	8.9834e-04	4.0799e-04	2.7438e-04
0.5LiCl-0.5MnCl2	6.3853e-04	3.3782e-04	2.5244e-04
0.6LiCl-0.4BeCl2	1.1206e-03	4.7340e-04	2.9424e-04
0.9LiCl-0.1CaCl2	5.5082e-04	3.4630e-04	2.7053e-04
0.5LiCl-0.5CoCl2	7.1851e-04	3.7998e-04	2.8099e-04
0.8LiCl-0.2MgCl2	6.4518e-04	3.6532e-04	2.7483e-04
0.5LiCl-0.5BeCl2	1.3538e-03	5.3113e-04	3.0216e-04
0.8LiCl-0.2NaCl	7.0379e-04	3.6718e-04	2.6445e-04
0.9LiCl-0.1KCl	5.3817e-04	3.4767e-04	2.7508e-04

APPENDIX C. TERNARY SALT TRITIUM PRODUCTION

APPENDIX C. TERNARY SALT TRITIUM PRODUCTION

Table 17. The ternary salt tritium production normalized to unenriched FLiBe tritium production.

Salt	Unenriched	90% Enriched ^{37}Cl	90% Enriched ^{6}Li-^{37}Cl
0.1KCl-0.8LiCl-0.1MgCl2	0.660780	0.740020	1.105940
0.1KCl-0.6LiCl-0.3PbCl2	0.660310	0.737670	1.129240
0.1KCl-0.7LiCl-0.2MgCl2	0.624920	0.703410	1.091850
0.2KCl-0.7LiCl-0.1MgCl2	0.605930	0.675010	1.074590
0.1KCl-0.5LiCl-0.4PbCl2	0.640760	0.717260	1.133080
0.1KCl-0.6LiCl-0.3MnCl2	0.583430	0.669090	1.112970
0.2KCl-0.6LiCl-0.2MnCl2	0.569720	0.649260	1.083250
0.1KCl-0.6LiCl-0.3MgCl2	0.582480	0.660710	1.075130
0.2KCl-0.5LiCl-0.3PbCl2	0.586500	0.652490	1.088650
0.2KCl-0.6LiCl-0.2MgCl2	0.565080	0.633800	1.057040
0.1KCl-0.4LiCl-0.5PbCl2	0.611770	0.687160	1.134090
0.1KCl-0.5LiCl-0.4MnCl2	0.528110	0.608490	1.104350
0.1KCl-0.5LiCl-0.4NaCl	0.549310	0.643540	1.048480
0.2KCl-0.5LiCl-0.3MnCl2	0.517540	0.593390	1.075900
0.2KCl-0.4LiCl-0.4PbCl2	0.553880	0.618320	1.083560
0.2KCl-0.5LiCl-0.3NaCl	0.531260	0.612820	1.031720
0.3KCl-0.5LiCl-0.2MnCl2	0.503670	0.573980	1.044000
0.1KCl-0.5LiCl-0.4MgCl2	0.532360	0.609780	1.053650
0.2KCl-0.5LiCl-0.3MgCl2	0.515880	0.583950	1.035400
0.3KCl-0.5LiCl-0.2MgCl2	0.498080	0.557780	1.015930
0.4KCl-0.5LiCl-0.1NaCl	0.486640	0.543090	0.993320
0.1KCl-0.4LiCl-0.5MnCl2	0.461120	0.533170	1.087300
0.2KCl-0.4LiCl-0.4MnCl2	0.452980	0.522620	1.059200
0.1KCl-0.4LiCl-0.5NaCl	0.491240	0.588890	1.020370
0.4KCl-0.4LiCl-0.2PbCl2	0.458250	0.504690	0.994760
0.1AlCl3-0.8LiCl-0.1PbCl2	0.440940	0.460980	0.982800
0.2KCl-0.4LiCl-0.4NaCl	0.475440	0.560550	1.003000
0.3KCl-0.4LiCl-0.3MnCl2	0.442600	0.508330	1.027800
0.1AlCl3-0.8LiCl-0.1NaCl	0.441820	0.466050	0.973790
0.1KCl-0.4LiCl-0.5MgCl2	0.471910	0.548430	1.026310
0.3KCl-0.4LiCl-0.3NaCl	0.457870	0.530410	0.983700
0.1CaCl2-0.1KCl-0.8LiCl	0.651230	0.724930	1.099310
0.1AlCl3-0.7LiCl-0.2PbCl2	0.417480	0.435290	0.968220
0.1AlCl3-0.8LiCl-0.1MgCl2	0.433810	0.455400	0.973110
0.4KCl-0.4LiCl-0.2MnCl2	0.429460	0.490140	0.994320
0.2KCl-0.4LiCl-0.4MgCl2	0.456760	0.524160	1.006680
0.5KCl-0.4LiCl-0.1PbCl2	0.418770	0.458200	0.954100
0.4KCl-0.4LiCl-0.2NaCl	0.437200	0.497670	0.962950
0.3KCl-0.4LiCl-0.3MgCl2	0.440870	0.499540	0.986000

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Table 17. The ternary salt tritium production normalized to unenriched FLiBe tritium production.

Salt	Unenriched	90% Enriched ^{37}Cl	90% Enriched ^{6}Li-^{37}Cl
0.5KCl-0.4LiCl-0.1MnCl2	0.412510	0.464900	0.957520
0.4KCl-0.4LiCl-0.2MgCl2	0.423870	0.474110	0.964470
0.8LiCl-0.1MgCl2-0.1PbCl2	0.705750	0.794210	1.138780
0.5KCl-0.4LiCl-0.1NaCl	0.414030	0.461690	0.941180
0.1AlCl3-0.6LiCl-0.3PbCl2	0.389050	0.404870	0.947820
0.8LiCl-0.1NaCl-0.1SrCl2	0.699840	0.793320	1.132330
0.2AlCl3-0.7LiCl-0.1PbCl2	0.268810	0.272040	0.768020
0.1AlCl3-0.7LiCl-0.2MnCl2	0.420930	0.451890	0.980190
0.5KCl-0.4LiCl-0.1MgCl2	0.405500	0.447680	0.941740
0.1CaCl2-0.7LiCl-0.2MnCl2	0.639710	0.734170	1.127090
0.1AlCl3-0.7LiCl-0.2NaCl	0.415110	0.440080	0.949890
0.8LiCl-0.1MgCl2-0.1NaCl	0.686520	0.781480	1.120730
0.2AlCl3-0.7LiCl-0.1MnCl2	0.278950	0.287200	0.782180
0.2AlCl3-0.7LiCl-0.1NaCl	0.273160	0.277940	0.769140
0.2AlCl3-0.1CaCl2-0.7LiCl	0.260960	0.264350	0.754830
0.2AlCl3-0.7LiCl-0.1MgCl2	0.267020	0.270920	0.767270
0.1BeCl2-0.1CaCl2-0.8LiCl	0.679280	0.768340	1.125820
0.2AlCl3-0.6LiCl-0.2PbCl2	0.242890	0.245200	0.731090
0.4KCl-0.3LiCl-0.3PbCl2	0.407070	0.451730	0.970510
0.7LiCl-0.1NaCl-0.2SrCl2	0.678660	0.773720	1.131040
0.1AlCl3-0.5LiCl-0.4PbCl2	0.354790	0.368420	0.920120
0.7LiCl-0.2MnCl2-0.1SrCl2	0.658280	0.755700	1.144450
0.2KCl-0.3LiCl-0.5MnCl2	0.374270	0.434200	1.028930
0.2CaCl2-0.7LiCl-0.1NaCl	0.636400	0.722250	1.094120
0.7LiCl-0.2NaCl-0.1SrCl2	0.666390	0.763820	1.116720
0.2CaCl2-0.1KCl-0.7LiCl	0.608720	0.677960	1.078370
0.7LiCl-0.2MnCl2-0.1NaCl	0.644670	0.744480	1.131030
0.6LiCl-0.1MgCl2-0.3PbCl2	0.684650	0.774980	1.150270
0.7LiCl-0.1MnCl2-0.2NaCl	0.646990	0.749850	1.117740
0.1AlCl3-0.6LiCl-0.3MnCl2	0.386650	0.416900	0.965100
0.7LiCl-0.1MgCl2-0.2MnCl2	0.644500	0.743810	1.132560
0.1CaCl2-0.6LiCl-0.3MnCl2	0.593250	0.684450	1.123090
0.7LiCl-0.1MgCl2-0.2NaCl	0.653520	0.752530	1.105790
0.3KCl-0.3LiCl-0.4MnCl2	0.366830	0.424850	0.998820
0.2KCl-0.3LiCl-0.5NaCl	0.403950	0.491420	0.963420
0.1AlCl3-0.6LiCl-0.3NaCl	0.383370	0.409080	0.922060
0.3AlCl3-0.6LiCl-0.1PbCl2	0.171270	0.170550	0.574810
0.5KCl-0.3LiCl-0.2PbCl2	0.367820	0.405740	0.925110
0.2AlCl3-0.6LiCl-0.2NaCl	0.248910	0.253630	0.735030
0.2AlCl3-0.5LiCl-0.3PbCl2	0.213770	0.215380	0.685370

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Table 17. The ternary salt tritium production normalized to unenriched FLiBe tritium production.

Salt	Unenriched	90% Enriched ^{37}Cl	90% Enriched ^{6}Li-^{37}Cl
0.5LiCl-0.1NaCl-0.4PbCl2	0.671180	0.768190	1.152570
0.3KCl-0.3LiCl-0.4NaCl	0.389420	0.464600	0.943350
0.6LiCl-0.1NaCl-0.3SrCl2	0.651400	0.746130	1.128430
0.3AlCl3-0.6LiCl-0.1MnCl2	0.179390	0.181180	0.592480
0.6LiCl-0.2MnCl2-0.2SrCl2	0.627160	0.723360	1.142320
0.4KCl-0.3LiCl-0.3MnCl2	0.357680	0.412270	0.965650
0.1KCl-0.3LiCl-0.6MgCl2	0.396920	0.471930	0.987410
0.3AlCl3-0.6LiCl-0.1NaCl	0.175030	0.174750	0.581310
0.6LiCl-0.3NaCl-0.1PbCl2	0.637420	0.738310	1.105060
0.5LiCl-0.1MgCl2-0.4PbCl2	0.666640	0.757250	1.154980
0.2BeCl2-0.7LiCl-0.1NaCl	0.659320	0.768140	1.126900
0.6LiCl-0.3MnCl2-0.1SrCl2	0.610400	0.704440	1.140910
0.1AlCl3-0.4LiCl-0.5PbCl2	0.313080	0.324410	0.881340
0.6LiCl-0.2NaCl-0.2SrCl2	0.638780	0.737140	1.112820
0.3AlCl3-0.6LiCl-0.1MgCl2	0.171030	0.170480	0.578850
0.2CaCl2-0.6LiCl-0.2MnCl2	0.590280	0.681090	1.105620
0.2KCl-0.3LiCl-0.5MgCl2	0.383850	0.449660	0.966140
0.4KCl-0.3LiCl-0.3NaCl	0.372820	0.436140	0.920870
0.6LiCl-0.3MnCl2-0.1NaCl	0.596760	0.692720	1.126800
0.6LiCl-0.3NaCl-0.1SrCl2	0.626040	0.726820	1.099170
0.2CaCl2-0.6LiCl-0.2NaCl	0.599440	0.689850	1.076980

Table 18. The ternary salt tritium production normalized to 30% ^{6}Li enriched FLiBe tritium production.

Salt	Unenriched	90% Enriched ^{37}Cl	90% Enriched ^{6}Li-^{37}Cl
0.1KCl-0.8LiCl-0.1MgCl2	0.601980	0.674180	1.007540
0.1KCl-0.6LiCl-0.3PbCl2	0.601560	0.672040	1.028770
0.1KCl-0.7LiCl-0.2MgCl2	0.569320	0.640820	0.994700
0.2KCl-0.7LiCl-0.1MgCl2	0.552020	0.614950	0.978980
0.1KCl-0.5LiCl-0.4PbCl2	0.583750	0.653440	1.032260
0.1KCl-0.6LiCl-0.3MnCl2	0.531520	0.609560	1.013950
0.2KCl-0.6LiCl-0.2MnCl2	0.519030	0.591490	0.986870
0.1KCl-0.6LiCl-0.3MgCl2	0.530650	0.601930	0.979470
0.2KCl-0.5LiCl-0.3PbCl2	0.534320	0.594430	0.991790
0.2KCl-0.6LiCl-0.2MgCl2	0.514800	0.577400	0.962990
0.1KCl-0.4LiCl-0.5PbCl2	0.557340	0.626020	1.033180
0.1KCl-0.5LiCl-0.4MnCl2	0.481120	0.554350	1.006090
0.1KCl-0.5LiCl-0.4NaCl	0.500440	0.586280	0.955190
0.2KCl-0.5LiCl-0.3MnCl2	0.471490	0.540600	0.980180
0.2KCl-0.4LiCl-0.4PbCl2	0.504600	0.563310	0.987150
0.2KCl-0.5LiCl-0.3NaCl	0.483990	0.558300	0.939920
0.3KCl-0.5LiCl-0.2MnCl2	0.458860	0.522910	0.951110
0.1KCl-0.5LiCl-0.4MgCl2	0.484990	0.555530	0.959910
0.2KCl-0.5LiCl-0.3MgCl2	0.469980	0.531990	0.943280
0.3KCl-0.5LiCl-0.2MgCl2	0.453760	0.508150	0.925540
0.4KCl-0.5LiCl-0.1NaCl	0.443340	0.494770	0.904940
0.1KCl-0.4LiCl-0.5MnCl2	0.420090	0.485730	0.990560
0.2KCl-0.4LiCl-0.4MnCl2	0.412670	0.476120	0.964960
0.1KCl-0.4LiCl-0.5NaCl	0.447530	0.536500	0.929580
0.4KCl-0.4LiCl-0.2PbCl2	0.417480	0.459790	0.906260
0.1AlCl3-0.8LiCl-0.1PbCl2	0.401710	0.419970	0.895350
0.2KCl-0.4LiCl-0.4NaCl	0.433140	0.510680	0.913760
0.3KCl-0.4LiCl-0.3MnCl2	0.403220	0.463100	0.936350
0.1AlCl3-0.8LiCl-0.1NaCl	0.402510	0.424580	0.887150
0.1KCl-0.4LiCl-0.5MgCl2	0.429920	0.499640	0.934990
0.3KCl-0.4LiCl-0.3NaCl	0.417140	0.483220	0.896180
0.1CaCl2-0.1KCl-0.8LiCl	0.593290	0.660430	1.001500
0.1AlCl3-0.7LiCl-0.2PbCl2	0.380340	0.396560	0.882070
0.1AlCl3-0.8LiCl-0.1MgCl2	0.395210	0.414880	0.886530
0.4KCl-0.4LiCl-0.2MnCl2	0.391250	0.446530	0.905850
0.2KCl-0.4LiCl-0.4MgCl2	0.416120	0.477530	0.917120
0.5KCl-0.4LiCl-0.1PbCl2	0.381510	0.417430	0.869210
0.4KCl-0.4LiCl-0.2NaCl	0.398300	0.453390	0.877280
0.3KCl-0.4LiCl-0.3MgCl2	0.401640	0.455090	0.898270

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Table 18. The ternary salt tritium production normalized to 30% ^{6}Li enriched FLiBe tritium production.

Salt	Unenriched	90% Enriched ^{37}Cl	90% Enriched ^{6}Li-^{37}Cl
0.5KCl-0.4LiCl-0.1MnCl2	0.375800	0.423530	0.872320
0.4KCl-0.4LiCl-0.2MgCl2	0.386150	0.431930	0.878650
0.8LiCl-0.1MgCl2-0.1PbCl2	0.642950	0.723540	1.037460
0.5KCl-0.4LiCl-0.1NaCl	0.377200	0.420610	0.857440
0.1AlCl3-0.6LiCl-0.3PbCl2	0.354440	0.368850	0.863490
0.8LiCl-0.1NaCl-0.1SrCl2	0.637570	0.722740	1.031590
0.2AlCl3-0.7LiCl-0.1PbCl2	0.244890	0.247840	0.699690
0.1AlCl3-0.7LiCl-0.2MnCl2	0.383480	0.411690	0.892980
0.5KCl-0.4LiCl-0.1MgCl2	0.369420	0.407850	0.857950
0.1CaCl2-0.7LiCl-0.2MnCl2	0.582790	0.668850	1.026810
0.1AlCl3-0.7LiCl-0.2NaCl	0.378170	0.400930	0.865380
0.8LiCl-0.1MgCl2-0.1NaCl	0.625440	0.711940	1.021010
0.2AlCl3-0.7LiCl-0.1MnCl2	0.254130	0.261640	0.712590
0.2AlCl3-0.7LiCl-0.1NaCl	0.248860	0.253210	0.700700
0.2AlCl3-0.1CaCl2-0.7LiCl	0.237740	0.240830	0.687670
0.2AlCl3-0.7LiCl-0.1MgCl2	0.243260	0.246820	0.699000
0.1BeCl2-0.1CaCl2-0.8LiCl	0.618840	0.699970	1.025650
0.2AlCl3-0.6LiCl-0.2PbCl2	0.221270	0.223380	0.666050
0.4KCl-0.3LiCl-0.3PbCl2	0.370850	0.411530	0.884160
0.7LiCl-0.1NaCl-0.2SrCl2	0.618280	0.704880	1.030410
0.1AlCl3-0.5LiCl-0.4PbCl2	0.323220	0.335640	0.838260
0.7LiCl-0.2MnCl2-0.1SrCl2	0.599710	0.688460	1.042620
0.2KCl-0.3LiCl-0.5MnCl2	0.340970	0.395570	0.937380
0.2CaCl2-0.7LiCl-0.1NaCl	0.579780	0.657990	0.996770
0.7LiCl-0.2NaCl-0.1SrCl2	0.607100	0.695860	1.017370
0.2CaCl2-0.1KCl-0.7LiCl	0.554560	0.617640	0.982420
0.7LiCl-0.2MnCl2-0.1NaCl	0.587320	0.678240	1.030390
0.6LiCl-0.1MgCl2-0.3PbCl2	0.623730	0.706030	1.047930
0.7LiCl-0.1MnCl2-0.2NaCl	0.589430	0.683140	1.018290
0.1AlCl3-0.6LiCl-0.3MnCl2	0.352240	0.379810	0.879230
0.7LiCl-0.1MgCl2-0.2MnCl2	0.587150	0.677630	1.031790
0.1CaCl2-0.6LiCl-0.3MnCl2	0.540460	0.623550	1.023160
0.7LiCl-0.1MgCl2-0.2NaCl	0.595370	0.685580	1.007400
0.3KCl-0.3LiCl-0.4MnCl2	0.334190	0.387050	0.909950
0.2KCl-0.3LiCl-0.5NaCl	0.368010	0.447700	0.877700
0.1AlCl3-0.6LiCl-0.3NaCl	0.349260	0.372690	0.840030
0.3AlCl3-0.6LiCl-0.1PbCl2	0.156040	0.155380	0.523670
0.5KCl-0.3LiCl-0.2PbCl2	0.335090	0.369640	0.842800
0.2AlCl3-0.6LiCl-0.2NaCl	0.226760	0.231060	0.669630

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Table 18. The ternary salt tritium production normalized to 30% ^{6}Li enriched FLiBe tritium production.

Salt	Unenriched	90% Enriched ^{37}Cl	90% Enriched ^{6}Li-^{37}Cl
0.2AlCl3-0.5LiCl-0.3PbCl2	0.194750	0.196220	0.624390
0.5LiCl-0.1NaCl-0.4PbCl2	0.611460	0.699840	1.050020
0.3KCl-0.3LiCl-0.4NaCl	0.354770	0.423260	0.859420
0.6LiCl-0.1NaCl-0.3SrCl2	0.593440	0.679740	1.028030
0.3AlCl3-0.6LiCl-0.1MnCl2	0.163430	0.165060	0.539760
0.6LiCl-0.2MnCl2-0.2SrCl2	0.571360	0.659000	1.040680
0.4KCl-0.3LiCl-0.3MnCl2	0.325860	0.375590	0.879730
0.1KCl-0.3LiCl-0.6MgCl2	0.361610	0.429940	0.899550
0.3AlCl3-0.6LiCl-0.1NaCl	0.159450	0.159200	0.529590
0.6LiCl-0.3NaCl-0.1PbCl2	0.580710	0.672620	1.006740
0.5LiCl-0.1MgCl2-0.4PbCl2	0.607330	0.689870	1.052220
0.2BeCl2-0.7LiCl-0.1NaCl	0.600660	0.699800	1.026630
0.6LiCl-0.3MnCl2-0.1SrCl2	0.556090	0.641760	1.039400
0.1AlCl3-0.4LiCl-0.5PbCl2	0.285230	0.295550	0.802920
0.6LiCl-0.2NaCl-0.2SrCl2	0.581940	0.671550	1.013810
0.3AlCl3-0.6LiCl-0.1MgCl2	0.155820	0.155310	0.527350
0.2CaCl2-0.6LiCl-0.2MnCl2	0.537760	0.620490	1.007250
0.2KCl-0.3LiCl-0.5MgCl2	0.349700	0.409660	0.880180
0.4KCl-0.3LiCl-0.3NaCl	0.339640	0.397340	0.838940
0.6LiCl-0.3MnCl2-0.1NaCl	0.543660	0.631090	1.026550
0.6LiCl-0.3NaCl-0.1SrCl2	0.570340	0.662160	1.001380
0.2CaCl2-0.6LiCl-0.2NaCl	0.546100	0.628470	0.981160

Table 19. The ternary salt tritium production normalized to 60% ^{6}Li enriched FLiBe tritium production.

Salt	Unenriched	90% Enriched ^{37}Cl	90% Enriched ^{6}Li-^{37}Cl
0.1KCl-0.8LiCl-0.1MgCl2	0.591230	0.662140	0.989540
0.1KCl-0.6LiCl-0.3PbCl2	0.590810	0.660030	1.010390
0.1KCl-0.7LiCl-0.2MgCl2	0.559150	0.629370	0.976930
0.2KCl-0.7LiCl-0.1MgCl2	0.542160	0.603970	0.961490
0.1KCl-0.5LiCl-0.4PbCl2	0.573320	0.641770	1.013820
0.1KCl-0.6LiCl-0.3MnCl2	0.522030	0.598670	0.995830
0.2KCl-0.6LiCl-0.2MnCl2	0.509760	0.580930	0.969240
0.1KCl-0.6LiCl-0.3MgCl2	0.521170	0.591170	0.961970
0.2KCl-0.5LiCl-0.3PbCl2	0.524780	0.583810	0.974070
0.2KCl-0.6LiCl-0.2MgCl2	0.505610	0.567090	0.945790
0.1KCl-0.4LiCl-0.5PbCl2	0.547380	0.614830	1.014720
0.1KCl-0.5LiCl-0.4MnCl2	0.472520	0.544450	0.988120
0.1KCl-0.5LiCl-0.4NaCl	0.491500	0.575810	0.938130
0.2KCl-0.5LiCl-0.3MnCl2	0.463060	0.530940	0.962660
0.2KCl-0.4LiCl-0.4PbCl2	0.495580	0.553240	0.969520
0.2KCl-0.5LiCl-0.3NaCl	0.475350	0.548320	0.923130
0.3KCl-0.5LiCl-0.2MnCl2	0.450660	0.513570	0.934120
0.1KCl-0.5LiCl-0.4MgCl2	0.476330	0.545600	0.942760
0.2KCl-0.5LiCl-0.3MgCl2	0.461590	0.522490	0.926430
0.3KCl-0.5LiCl-0.2MgCl2	0.445660	0.499070	0.909010
0.4KCl-0.5LiCl-0.1NaCl	0.435420	0.485930	0.888780
0.1KCl-0.4LiCl-0.5MnCl2	0.412590	0.477050	0.972860
0.2KCl-0.4LiCl-0.4MnCl2	0.405300	0.467610	0.947720
0.1KCl-0.4LiCl-0.5NaCl	0.439530	0.526910	0.912980
0.4KCl-0.4LiCl-0.2PbCl2	0.410020	0.451570	0.890060
0.1AlCl3-0.8LiCl-0.1PbCl2	0.394530	0.412460	0.879360
0.2KCl-0.4LiCl-0.4NaCl	0.425400	0.501560	0.897440
0.3KCl-0.4LiCl-0.3MnCl2	0.396020	0.454830	0.919620
0.1AlCl3-0.8LiCl-0.1NaCl	0.395320	0.417000	0.871300
0.1KCl-0.4LiCl-0.5MgCl2	0.422240	0.490710	0.918290
0.3KCl-0.4LiCl-0.3NaCl	0.409680	0.474580	0.880170
0.1CaCl2-0.1KCl-0.8LiCl	0.582690	0.648630	0.983610
0.1AlCl3-0.7LiCl-0.2PbCl2	0.373540	0.389480	0.866310
0.1AlCl3-0.8LiCl-0.1MgCl2	0.388150	0.407470	0.870690
0.4KCl-0.4LiCl-0.2MnCl2	0.384260	0.438550	0.889670
0.2KCl-0.4LiCl-0.4MgCl2	0.408690	0.469000	0.900730
0.5KCl-0.4LiCl-0.1PbCl2	0.374690	0.409970	0.853680
0.4KCl-0.4LiCl-0.2NaCl	0.391190	0.445290	0.861600
0.3KCl-0.4LiCl-0.3MgCl2	0.394470	0.446960	0.882220

Continued on next page

Table 19. The ternary salt tritium production normalized to 60% ^{6}Li enriched FLiBe tritium production.

Salt	Unenriched	90% Enriched ^{37}Cl	90% Enriched ^{6}Li-^{37}Cl
0.5KCl-0.4LiCl-0.1MnCl2	0.369090	0.415970	0.856740
0.4KCl-0.4LiCl-0.2MgCl2	0.379250	0.424210	0.862960
0.8LiCl-0.1MgCl2-0.1PbCl2	0.631470	0.710620	1.018930
0.5KCl-0.4LiCl-0.1NaCl	0.370460	0.413100	0.842120
0.1AlCl3-0.6LiCl-0.3PbCl2	0.348100	0.362260	0.848060
0.8LiCl-0.1NaCl-0.1SrCl2	0.626180	0.709830	1.013160
0.2AlCl3-0.7LiCl-0.1PbCl2	0.240520	0.243410	0.687180
0.1AlCl3-0.7LiCl-0.2MnCl2	0.376620	0.404330	0.877020
0.5KCl-0.4LiCl-0.1MgCl2	0.362820	0.400560	0.842620
0.1CaCl2-0.7LiCl-0.2MnCl2	0.572380	0.656900	1.008460
0.1AlCl3-0.7LiCl-0.2NaCl	0.371420	0.393760	0.849920
0.8LiCl-0.1MgCl2-0.1NaCl	0.614270	0.699220	1.002770
0.2AlCl3-0.7LiCl-0.1MnCl2	0.249590	0.256970	0.699860
0.2AlCl3-0.7LiCl-0.1NaCl	0.244410	0.248690	0.688180
0.2AlCl3-0.1CaCl2-0.7LiCl	0.233490	0.236530	0.675380
0.2AlCl3-0.7LiCl-0.1MgCl2	0.238920	0.242410	0.686520
0.1BeCl2-0.1CaCl2-0.8LiCl	0.607790	0.687470	1.007330
0.2AlCl3-0.6LiCl-0.2PbCl2	0.217320	0.219390	0.654150
0.4KCl-0.3LiCl-0.3PbCl2	0.364230	0.404180	0.868360
0.7LiCl-0.1NaCl-0.2SrCl2	0.607230	0.692290	1.012000
0.1AlCl3-0.5LiCl-0.4PbCl2	0.317450	0.329650	0.823280
0.7LiCl-0.2MnCl2-0.1SrCl2	0.589000	0.676160	1.024000
0.2KCl-0.3LiCl-0.5MnCl2	0.334880	0.388500	0.920640
0.2CaCl2-0.7LiCl-0.1NaCl	0.569420	0.646240	0.978960
0.7LiCl-0.2NaCl-0.1SrCl2	0.596260	0.683430	0.999190
0.2CaCl2-0.1KCl-0.7LiCl	0.544660	0.606600	0.964870
0.7LiCl-0.2MnCl2-0.1NaCl	0.576820	0.666120	1.011980
0.6LiCl-0.1MgCl2-0.3PbCl2	0.612590	0.693420	1.029200
0.7LiCl-0.1MnCl2-0.2NaCl	0.578900	0.670930	1.000090
0.1AlCl3-0.6LiCl-0.3MnCl2	0.345950	0.373020	0.863520
0.7LiCl-0.1MgCl2-0.2MnCl2	0.576660	0.665520	1.013350
0.1CaCl2-0.6LiCl-0.3MnCl2	0.530810	0.612410	1.004880
0.7LiCl-0.1MgCl2-0.2NaCl	0.584730	0.673330	0.989410
0.3KCl-0.3LiCl-0.4MnCl2	0.328220	0.380130	0.893700
0.2KCl-0.3LiCl-0.5NaCl	0.361440	0.439700	0.862020
0.1AlCl3-0.6LiCl-0.3NaCl	0.343020	0.366030	0.825020
0.3AlCl3-0.6LiCl-0.1PbCl2	0.153250	0.152600	0.514320
0.5KCl-0.3LiCl-0.2PbCl2	0.329110	0.363030	0.827750
0.2AlCl3-0.6LiCl-0.2NaCl	0.222710	0.226940	0.657670

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Table 19. The ternary salt tritium production normalized to 60% ^{6}Li enriched FLiBe tritium production.

Salt	Unenriched	90% Enriched ^{37}Cl	90% Enriched ^{6}Li-^{37}Cl
0.2AlCl3-0.5LiCl-0.3PbCl2	0.191270	0.192710	0.613230
0.5LiCl-0.1NaCl-0.4PbCl2	0.600540	0.687340	1.031260
0.3KCl-0.3LiCl-0.4NaCl	0.348430	0.415700	0.844060
0.6LiCl-0.1NaCl-0.3SrCl2	0.582840	0.667600	1.009660
0.3AlCl3-0.6LiCl-0.1MnCl2	0.160510	0.162110	0.530120
0.6LiCl-0.2MnCl2-0.2SrCl2	0.561160	0.647230	1.022090
0.4KCl-0.3LiCl-0.3MnCl2	0.320030	0.368880	0.864020
0.1KCl-0.3LiCl-0.6MgCl2	0.355150	0.422260	0.883480
0.3AlCl3-0.6LiCl-0.1NaCl	0.156600	0.156360	0.520130
0.6LiCl-0.3NaCl-0.1PbCl2	0.570330	0.660610	0.988750
0.5LiCl-0.1MgCl2-0.4PbCl2	0.596480	0.677550	1.033420
0.2BeCl2-0.7LiCl-0.1NaCl	0.589920	0.687300	1.008290
0.6LiCl-0.3MnCl2-0.1SrCl2	0.546160	0.630300	1.020830
0.1AlCl3-0.4LiCl-0.5PbCl2	0.280130	0.290270	0.788580
0.6LiCl-0.2NaCl-0.2SrCl2	0.571550	0.659550	0.995700
0.3AlCl3-0.6LiCl-0.1MgCl2	0.153030	0.152540	0.517930
0.2CaCl2-0.6LiCl-0.2MnCl2	0.528160	0.609410	0.989260
0.2KCl-0.3LiCl-0.5MgCl2	0.343450	0.402340	0.864450
0.4KCl-0.3LiCl-0.3NaCl	0.333580	0.390240	0.823950
0.6LiCl-0.3MnCl2-0.1NaCl	0.533950	0.619810	1.008210
0.6LiCl-0.3NaCl-0.1SrCl2	0.560150	0.650330	0.983490
0.2CaCl2-0.6LiCl-0.2NaCl	0.536350	0.617240	0.963630

Table 20. The ternary salt tritium production normalized to 90% ^{6}Li enriched FLiBe tritium production.

Salt	Unenriched	90% Enriched ^{37}Cl	90% Enriched ^{6}Li-^{37}Cl
0.1KCl-0.8LiCl-0.1MgCl2	0.593580	0.664770	0.993470
0.1KCl-0.6LiCl-0.3PbCl2	0.593160	0.662660	1.014400
0.1KCl-0.7LiCl-0.2MgCl2	0.561370	0.631880	0.980810
0.2KCl-0.7LiCl-0.1MgCl2	0.544310	0.606370	0.965310
0.1KCl-0.5LiCl-0.4PbCl2	0.575600	0.644320	1.017850
0.1KCl-0.6LiCl-0.3MnCl2	0.524100	0.601050	0.999790
0.2KCl-0.6LiCl-0.2MnCl2	0.511790	0.583230	0.973090
0.1KCl-0.6LiCl-0.3MgCl2	0.523240	0.593520	0.965790
0.2KCl-0.5LiCl-0.3PbCl2	0.526860	0.586130	0.977940
0.2KCl-0.6LiCl-0.2MgCl2	0.507620	0.569340	0.949550
0.1KCl-0.4LiCl-0.5PbCl2	0.549550	0.617280	1.018760
0.1KCl-0.5LiCl-0.4MnCl2	0.474400	0.546610	0.992040
0.1KCl-0.5LiCl-0.4NaCl	0.493450	0.578100	0.941860
0.2KCl-0.5LiCl-0.3MnCl2	0.464900	0.533050	0.966490
0.2KCl-0.4LiCl-0.4PbCl2	0.497550	0.555440	0.973370
0.2KCl-0.5LiCl-0.3NaCl	0.477240	0.550500	0.926800
0.3KCl-0.5LiCl-0.2MnCl2	0.452450	0.515610	0.937830
0.1KCl-0.5LiCl-0.4MgCl2	0.478220	0.547770	0.946500
0.2KCl-0.5LiCl-0.3MgCl2	0.463420	0.524560	0.930110
0.3KCl-0.5LiCl-0.2MgCl2	0.447430	0.501060	0.912620
0.4KCl-0.5LiCl-0.1NaCl	0.437150	0.487860	0.892310
0.1KCl-0.4LiCl-0.5MnCl2	0.414220	0.478950	0.976730
0.2KCl-0.4LiCl-0.4MnCl2	0.406910	0.469470	0.951480
0.1KCl-0.4LiCl-0.5NaCl	0.441280	0.529000	0.916600
0.4KCl-0.4LiCl-0.2PbCl2	0.411650	0.453370	0.893600
0.1AlCl3-0.8LiCl-0.1PbCl2	0.396100	0.414100	0.882850
0.2KCl-0.4LiCl-0.4NaCl	0.427090	0.503550	0.901000
0.3KCl-0.4LiCl-0.3MnCl2	0.397590	0.456640	0.923280
0.1AlCl3-0.8LiCl-0.1NaCl	0.396890	0.418660	0.874760
0.1KCl-0.4LiCl-0.5MgCl2	0.423920	0.492660	0.921940
0.3KCl-0.4LiCl-0.3NaCl	0.411310	0.476470	0.883660
0.1CaCl2-0.1KCl-0.8LiCl	0.585000	0.651210	0.987520
0.1AlCl3-0.7LiCl-0.2PbCl2	0.375030	0.391020	0.869760
0.1AlCl3-0.8LiCl-0.1MgCl2	0.389690	0.409090	0.874150
0.4KCl-0.4LiCl-0.2MnCl2	0.385790	0.440290	0.893200
0.2KCl-0.4LiCl-0.4MgCl2	0.410310	0.470860	0.904310
0.5KCl-0.4LiCl-0.1PbCl2	0.376180	0.411600	0.857070
0.4KCl-0.4LiCl-0.2NaCl	0.392740	0.447060	0.865030
0.3KCl-0.4LiCl-0.3MgCl2	0.396030	0.448740	0.885730

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Table 20. The ternary salt tritium production normalized to 90% ^{6}Li enriched FLiBe tritium production.

Salt	Unenriched	90% Enriched ^{37}Cl	90% Enriched ^{6}Li-^{37}Cl
0.5KCl-0.4LiCl-0.1MnCl2	0.370560	0.417620	0.860140
0.4KCl-0.4LiCl-0.2MgCl2	0.380760	0.425900	0.866380
0.8LiCl-0.1MgCl2-0.1PbCl2	0.633980	0.713440	1.022980
0.5KCl-0.4LiCl-0.1NaCl	0.371930	0.414740	0.845470
0.1AlCl3-0.6LiCl-0.3PbCl2	0.349490	0.363700	0.851430
0.8LiCl-0.1NaCl-0.1SrCl2	0.628670	0.712650	1.017180
0.2AlCl3-0.7LiCl-0.1PbCl2	0.241470	0.244380	0.689920
0.1AlCl3-0.7LiCl-0.2MnCl2	0.378120	0.405940	0.880510
0.5KCl-0.4LiCl-0.1MgCl2	0.364270	0.402150	0.845970
0.1CaCl2-0.7LiCl-0.2MnCl2	0.574650	0.659510	1.012470
0.1AlCl3-0.7LiCl-0.2NaCl	0.372890	0.395330	0.853290
0.8LiCl-0.1MgCl2-0.1NaCl	0.616710	0.702000	1.006760
0.2AlCl3-0.7LiCl-0.1MnCl2	0.250580	0.257990	0.702640
0.2AlCl3-0.7LiCl-0.1NaCl	0.245380	0.249670	0.690920
0.2AlCl3-0.1CaCl2-0.7LiCl	0.234420	0.237470	0.678060
0.2AlCl3-0.7LiCl-0.1MgCl2	0.239870	0.243370	0.689240
0.1BeCl2-0.1CaCl2-0.8LiCl	0.610200	0.690200	1.011330
0.2AlCl3-0.6LiCl-0.2PbCl2	0.218190	0.220260	0.656750
0.4KCl-0.3LiCl-0.3PbCl2	0.365670	0.405790	0.871810
0.7LiCl-0.1NaCl-0.2SrCl2	0.609640	0.695040	1.016020
0.1AlCl3-0.5LiCl-0.4PbCl2	0.318710	0.330960	0.826550
0.7LiCl-0.2MnCl2-0.1SrCl2	0.591340	0.678850	1.028070
0.2KCl-0.3LiCl-0.5MnCl2	0.336210	0.390050	0.924300
0.2CaCl2-0.7LiCl-0.1NaCl	0.571680	0.648800	0.982850
0.7LiCl-0.2NaCl-0.1SrCl2	0.598630	0.686140	1.003160
0.2CaCl2-0.1KCl-0.7LiCl	0.546820	0.609020	0.968700
0.7LiCl-0.2MnCl2-0.1NaCl	0.579110	0.668770	1.016010
0.6LiCl-0.1MgCl2-0.3PbCl2	0.615020	0.696170	1.033290
0.7LiCl-0.1MnCl2-0.2NaCl	0.581200	0.673600	1.004070
0.1AlCl3-0.6LiCl-0.3MnCl2	0.347330	0.374500	0.866950
0.7LiCl-0.1MgCl2-0.2MnCl2	0.578960	0.668170	1.017380
0.1CaCl2-0.6LiCl-0.3MnCl2	0.532920	0.614850	1.008880
0.7LiCl-0.1MgCl2-0.2NaCl	0.587060	0.676010	0.993340
0.3KCl-0.3LiCl-0.4MnCl2	0.329520	0.381640	0.897250
0.2KCl-0.3LiCl-0.5NaCl	0.362870	0.441450	0.865450
0.1AlCl3-0.6LiCl-0.3NaCl	0.344380	0.367480	0.828300
0.3AlCl3-0.6LiCl-0.1PbCl2	0.153860	0.153210	0.516360
0.5KCl-0.3LiCl-0.2PbCl2	0.330410	0.364470	0.831040
0.2AlCl3-0.6LiCl-0.2NaCl	0.223590	0.227840	0.660280

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Table 20. The ternary salt tritium production normalized to 90% ^{6}Li enriched FLiBe tritium production.

Salt	Unenriched	90% Enriched ^{37}Cl	90% Enriched ^{6}Li-^{37}Cl
0.2AlCl3-0.5LiCl-0.3PbCl2	0.192030	0.193480	0.615670
0.5LiCl-0.1NaCl-0.4PbCl2	0.602930	0.690070	1.035360
0.3KCl-0.3LiCl-0.4NaCl	0.349810	0.417350	0.847420
0.6LiCl-0.1NaCl-0.3SrCl2	0.585160	0.670250	1.013670
0.3AlCl3-0.6LiCl-0.1MnCl2	0.161150	0.162750	0.532230
0.6LiCl-0.2MnCl2-0.2SrCl2	0.563390	0.649800	1.026150
0.4KCl-0.3LiCl-0.3MnCl2	0.321310	0.370350	0.867450
0.1KCl-0.3LiCl-0.6MgCl2	0.356560	0.423930	0.886990
0.3AlCl3-0.6LiCl-0.1NaCl	0.157230	0.156980	0.522190
0.6LiCl-0.3NaCl-0.1PbCl2	0.572600	0.663230	0.992680
0.5LiCl-0.1MgCl2-0.4PbCl2	0.598850	0.680240	1.037530
0.2BeCl2-0.7LiCl-0.1NaCl	0.592270	0.690030	1.012300
0.6LiCl-0.3MnCl2-0.1SrCl2	0.548330	0.632800	1.024890
0.1AlCl3-0.4LiCl-0.5PbCl2	0.281250	0.291420	0.791710
0.6LiCl-0.2NaCl-0.2SrCl2	0.573820	0.662170	0.999650
0.3AlCl3-0.6LiCl-0.1MgCl2	0.153640	0.153150	0.519980
0.2CaCl2-0.6LiCl-0.2MnCl2	0.530260	0.611830	0.993190
0.2KCl-0.3LiCl-0.5MgCl2	0.344810	0.403940	0.867890
0.4KCl-0.3LiCl-0.3NaCl	0.334900	0.391790	0.827220
0.6LiCl-0.3MnCl2-0.1NaCl	0.536070	0.622270	1.012210
0.6LiCl-0.3NaCl-0.1SrCl2	0.562370	0.652910	0.987390
0.2CaCl2-0.6LiCl-0.2NaCl	0.538480	0.619690	0.967460

Table 21. The production of ^{36}Cl (atoms/b-cm) for ternary salts with a tritium production greater than FLiBe.

Salt	Unenriched	90% Enriched ^{37}Cl	90% Enriched ^{6}Li-^{37}Cl
0.5LiCl-0.1MgCl2-0.4PbCl2	7.8273e-04	3.7855e-04	2.6636e-04
0.5LiCl-0.1NaCl-0.4PbCl2	8.4215e-04	3.8460e-04	2.5941e-04
0.6LiCl-0.1MgCl2-0.3PbCl2	7.0895e-04	3.6826e-04	2.6769e-04
0.7LiCl-0.2MnCl2-0.1SrCl2	5.7757e-04	3.4049e-04	2.6215e-04
0.6LiCl-0.2MnCl2-0.2SrCl2	6.2431e-04	3.4792e-04	2.6302e-04
0.6LiCl-0.3MnCl2-0.1SrCl2	6.1106e-04	3.4172e-04	2.5896e-04
0.8LiCl-0.1MgCl2-0.1PbCl2	6.1308e-04	3.5603e-04	2.7043e-04
0.1KCl-0.4LiCl-0.5PbCl2	7.8301e-04	3.7806e-04	2.6959e-04
0.1KCl-0.5LiCl-0.4PbCl2	7.0190e-04	3.6734e-04	2.7073e-04
0.7LiCl-0.1MgCl2-0.2MnCl2	6.0146e-04	3.4734e-04	2.6500e-04
0.8LiCl-0.1NaCl-0.1SrCl2	6.6191e-04	3.6174e-04	2.6678e-04
0.7LiCl-0.1NaCl-0.2SrCl2	7.2070e-04	3.7267e-04	2.6759e-04
0.7LiCl-0.2MnCl2-0.1NaCl	6.0618e-04	3.4312e-04	2.6001e-04
0.1KCl-0.6LiCl-0.3PbCl2	6.4369e-04	3.6000e-04	2.7199e-04
0.6LiCl-0.1NaCl-0.3SrCl2	7.9543e-04	3.8598e-04	2.6851e-04
0.1CaCl2-0.7LiCl-0.2MnCl2	5.7560e-04	3.4161e-04	2.6432e-04
0.2BeCl2-0.7LiCl-0.1NaCl	9.1403e-04	4.1922e-04	2.7865e-04
0.6LiCl-0.3MnCl2-0.1NaCl	6.3779e-04	3.4435e-04	2.5681e-04
0.1BeCl2-0.1CaCl2-0.8LiCl	6.7600e-04	3.7306e-04	2.7681e-04
0.1CaCl2-0.6LiCl-0.3MnCl2	6.0996e-04	3.4331e-04	2.6131e-04
0.8LiCl-0.1MgCl2-0.1NaCl	6.9073e-04	3.6962e-04	2.6942e-04
0.7LiCl-0.1MnCl2-0.2NaCl	6.5571e-04	3.5366e-04	2.6096e-04
0.7LiCl-0.2NaCl-0.1SrCl2	7.6813e-04	3.7892e-04	2.6508e-04

APPENDIX D. BINARY SALT THERMOPHYSICAL DATA

APPENDIX D. BINARY SALT THERMOPHYSICAL DATA

Data availability of the most promising binary salts, sorted by tritium production in descending order and evaluated at 873 K [600°C]

Salt	^{3}H Production	$T_{liquidus}$ [K]	ρ [g/cm^3]	μ [mPa · s]	k [W/m · K]	c_p [J/mol · K]	ρ_{id} wt.%>wt.% [Bool]
66LiF-33BeF$_2$ [mol%]	1.000	773	1.984	8.535	1.1	79.9	F
H_2O_{PWR}	N/A	N/A	0.720	0.09	0.54	103.2	F
0.3LiCl-0.7PbCl2	1.072	697	2.873	N/A	N/A	N/A	T
0.4LiCl-0.6PbCl2	1.067	667	2.542	N/A	N/A	N/A	T
0.2LiCl-0.8PbCl2	1.066	725	3.304	N/A	N/A	N/A	T
0.5LiCl-0.5PbCl2	1.060	699	2.279	N/A	N/A	N/A	T
0.6LiCl-0.4PbCl2	1.053	740	2.065	N/A	N/A	N/A	T
0.7LiCl-0.3PbCl2	1.046	778	1.888	N/A	N/A	N/A	T
0.8LiCl-0.2PbCl2	1.039	815	1.739	N/A	N/A	N/A	T
0.9LiCl-0.1PbCl2	1.033	849	1.612	N/A	N/A	N/A	T
0.8LiCl-0.2SrCl2	1.029	816	1.661	2.413	0.615	61.052	F
0.9LiCl-0.1SrCl2	1.028	849	1.577	1.969	0.623	63.244	F
0.7LiCl-0.3SrCl2	1.028	784	1.753	2.941	0.607	58.448	F
0.7LiCl-0.3MnCl2	1.028	852	1.684	N/A	N/A	N/A	T
0.9LiCl-0.1BeCl2	1.027	849	1.482	1.557	0.595	61.56	F
0.6LiCl-0.4SrCl2	1.027	787	1.857	3.58	0.596	55.303	F
0.9LiCl-0.1CoCl2	1.026	876	1.565	N/A	N/A	N/A	T
0.8LiCl-0.2BeCl2	1.026	815	1.462	1.521	0.557	57.629	F
0.8LiCl-0.2CoCl2	1.025	849	1.633	N/A	N/A	N/A	T
0.6LiCl-0.4MnCl2	1.024	849	1.755	N/A	N/A	N/A	T
0.5LiCl-0.5SrCl2	1.024	841	1.974	4.366	0.583	51.429	F
0.7LiCl-0.3BeCl2	1.022	778	1.443	1.482	0.514	53.257	F
0.7LiCl-0.3CoCl2	1.022	818	1.708	N/A	N/A	N/A	T
0.1LiCl-0.9PbCl2	1.020	750	3.887	N/A	N/A	N/A	T
0.9LiCl-0.1MgCl2	1.018	847	1.524	1.656	0.609	66.364	F
0.6LiCl-0.4CoCl2	1.017	792	1.790	N/A	N/A	N/A	T
0.9LiCl-0.1NaCl	1.017	848	1.517	1.608	0.623	65.562	F
0.4LiCl-0.6SrCl2	1.016	898	2.107	5.358	0.567	46.538	F
0.5LiCl-0.5MnCl2	1.016	829	1.833	N/A	N/A	N/A	T
0.6LiCl-0.4BeCl2	1.016	740	1.424	1.438	0.467	48.364	F
0.9LiCl-0.1CaCl2	1.013	848	1.549	1.814	0.622	66.62	F
0.5LiCl-0.5CoCl2	1.009	836	1.880	N/A	N/A	N/A	T
0.8LiCl-0.2MgCl2	1.008	800	1.546	1.732	0.587	67.773	F
0.5LiCl-0.5BeCl2	1.006	699	1.406	1.388	0.414	42.852	F
0.8LiCl-0.2NaCl	1.005	808	1.532	1.629	0.618	66.038	F
0.9LiCl-0.1KCl	1.004	797	1.514	1.608	0.616	65.615	F
0.8LiCl-0.2CaCl2	0.996	811	1.599	2.07	0.615	68.34	F
0.7LiCl-0.3MgCl2	0.996	736	1.569	1.817	0.562	69.373	F
0.4LiCl-0.6CoCl2	0.995	882	1.980	N/A	N/A	N/A	T

0.7LiCl-0.3NaCl	0.991	764	1.547	1.651	0.611	66.543	F
0.4LiCl-0.6BeCl2	0.989	653	1.388	1.331	0.353	36.596	F
0.6LiCl-0.4MgCl2	0.981	801	1.593	1.916	0.533	71.204	F
0.7LiCl-0.3CaCl2	0.978	769	1.652	2.366	0.606	70.324	F
0.8LiCl-0.2KCl	0.978	797	1.526	1.628	0.603	66.164	F
0.6LiCl-0.4NaCl	0.975	773	1.563	1.674	0.605	67.08	F
0.5LiCl-0.5MgCl2	0.963	852	1.618	2.029	0.5	73.321	F
0.3LiCl-0.7BeCl2	0.962	601	1.370	1.266	0.284	29.435	F
0.6LiCl-0.4CaCl2	0.957	781	1.709	2.71	0.596	72.636	F
0.5LiCl-0.5NaCl	0.956	840	1.579	1.698	0.598	67.652	F
0.7LiCl-0.3KCl	0.947	786	1.538	1.651	0.588	66.768	F
0.4LiCl-0.6MgCl2	0.939	890	1.644	2.162	0.461	75.797	F
0.4LiCl-0.6NaCl	0.932	898	1.596	1.724	0.59	68.263	F
0.5LiCl-0.5CaCl2	0.930	840	1.770	3.117	0.585	75.367	F
0.2LiCl-0.8MnCl2	0.915	883	2.112	N/A	N/A	N/A	T
0.6LiCl-0.4KCl	0.914	716	1.551	1.676	0.571	67.435	F
0.2LiCl-0.8BeCl2	0.913	537	1.353	1.191	0.204	21.155	F
0.3LiCl-0.7NaCl	0.899	950	1.613	1.752	0.583	68.917	F
0.4LiCl-0.6CaCl2	0.897	891	1.836	3.605	0.571	78.641	F
0.9LiCl-0.1AlCl3	0.894	865	0.903	1.537	0.608	67.14	F
0.5LiCl-0.5KCl	0.873	634	1.564	1.703	0.553	68.177	F
0.2LiCl-0.8NaCl	0.847	996	1.630	1.783	0.574	69.619	F
0.4LiCl-0.6KCl	0.822	625	1.577	1.734	0.532	69.006	F
0.1LiCl-0.9BeCl2	0.803	451	1.336	1.104	0.111	11.473	F
0.3LiCl-0.7KCl	0.756	797	1.590	1.769	0.509	69.938	F
0.1LiCl-0.9NaCl	0.744	1037	1.648	1.815	0.565	70.374	F
0.8LiCl-0.2AlCl3	0.720	858	0.645	1.476	0.583	69.489	F
0.2LiCl-0.8KCl	0.659	878	1.603	1.809	0.482	70.995	F
0.7LiCl-0.3AlCl3	0.557	853	0.501	1.405	0.555	72.245	F
0.6LiCl-0.4AlCl3	0.421	822	0.410	1.321	0.52	75.525	F
0.5LiCl-0.5AlCl3	0.311	418	0.346	1.219	0.479	79.491	F
0.4LiCl-0.6AlCl3	0.222	401	0.300	1.093	0.428	84.387	F
0.3LiCl-0.7AlCl3	0.151	450	0.264	0.933	0.364	90.58	F
0.2LiCl-0.8AlCl3	0.093	460	0.236	0.725	0.28	98.666	F
0.1LiCl-0.9AlCl3	0.044	506	0.213	0.441	0.165	109.671	F

APPENDIX E. TERNARY SALT THERMOPHYSICAL DATA

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Data availability of the most promising ternary salts, sorted by tritium production in descending order evaluated at 873 K [600°C]

Salt	^3H Production	$T_{liquidus}$ [K]	ρ [g/cm^3]	μ [mPa · s]	k [W/m · K]	c_p [J/mol · K]	ρ_{id} wt.%>wt.% [Bool]
66LiF-33BeF$_2$ [mol%]	1.000	773	1.984	8.535	1.1	79.9	F
H_2O_{PWR}	N/A	N/A	0.720	0.09	0.54	103.2	F
0.5LiCl-0.1MgCl2-0.4PbCl2	1.038	678	2.107	N/A	N/A	N/A	T
0.5LiCl-0.1NaCl-0.4PbCl2	1.035	696	2.094	N/A	N/A	N/A	T
0.6LiCl-0.1MgCl2-0.3PbCl2	1.033	723	1.923	N/A	N/A	N/A	T
0.7LiCl-0.2MnCl2-0.1SrCl2	1.028	816	1.707	N/A	N/A	N/A	T
0.6LiCl-0.2MnCl2-0.2SrCl2	1.026	798	1.805	N/A	N/A	N/A	T
0.6LiCl-0.3MnCl2-0.1SrCl2	1.025	827	1.780	N/A	N/A	N/A	T
0.8LiCl-0.1MgCl2-0.1PbCl2	1.023	806	1.637	N/A	N/A	N/A	T
0.1KCl-0.4LiCl-0.5PbCl2	1.019	660	2.307	N/A	N/A	N/A	T
0.1KCl-0.5LiCl-0.4PbCl2	1.018	699	2.088	N/A	N/A	N/A	T
0.7LiCl-0.1MgCl2-0.2MnCl2	1.017	816	1.644	N/A	N/A	N/A	T
0.8LiCl-0.1NaCl-0.1SrCl2	1.017	815	1.594	N/A	N/A	N/A	T
0.7LiCl-0.1NaCl-0.2SrCl2	1.016	782	1.680	N/A	N/A	N/A	T
0.7LiCl-0.2MnCl2-0.1NaCl	1.016	803	1.636	N/A	N/A	N/A	T
0.1KCl-0.6LiCl-0.3PbCl2	1.014	735	1.907	N/A	N/A	N/A	T
0.6LiCl-0.1NaCl-0.3SrCl2	1.014	747	1.775	N/A	N/A	N/A	T
0.1CaCl2-0.7LiCl-0.2MnCl2	1.012	819	1.674	N/A	N/A	N/A	T
0.2BeCl2-0.7LiCl-0.1NaCl	1.012	773	1.476	N/A	N/A	N/A	T
0.6LiCl-0.3MnCl2-0.1NaCl	1.012	822	1.703	N/A	N/A	N/A	T
0.1BeCl2-0.1CaCl2-0.8LiCl	1.011	813	1.527	N/A	N/A	N/A	T
0.1CaCl2-0.6LiCl-0.3MnCl2	1.009	825	1.744	N/A	N/A	N/A	T
0.8LiCl-0.1MgCl2-0.1NaCl	1.007	814	1.539	N/A	N/A	N/A	T
0.7LiCl-0.1MnCl2-0.2NaCl	1.004	778	1.591	N/A	N/A	N/A	T
0.7LiCl-0.2NaCl-0.1SrCl2	1.003	775	1.611	N/A	N/A	N/A	T
0.1KCl-0.6LiCl-0.3MnCl2	1.000	820	1.699	N/A	N/A	N/A	T
0.6LiCl-0.2NaCl-0.2SrCl2	1.000	737	1.698	N/A	N/A	N/A	T
0.1KCl-0.8LiCl-0.1MgCl2	0.993	824	1.536	N/A	N/A	N/A	T
0.7LiCl-0.1MgCl2-0.2NaCl	0.993	778	1.555	N/A	N/A	N/A	T
0.2CaCl2-0.6LiCl-0.2MnCl2	0.993	801	1.733	N/A	N/A	N/A	T
0.6LiCl-0.3NaCl-0.1PbCl2	0.993	725	1.665	N/A	N/A	N/A	T
0.1KCl-0.5LiCl-0.4MnCl2	0.992	820	1.772	N/A	N/A	N/A	T
0.1CaCl2-0.1KCl-0.8LiCl	0.988	811	1.562	N/A	N/A	N/A	T
0.6LiCl-0.3NaCl-0.1SrCl2	0.987	726	1.628	N/A	N/A	N/A	T
0.2CaCl2-0.7LiCl-0.1NaCl	0.983	774	1.616	N/A	N/A	N/A	T
0.1KCl-0.7LiCl-0.2MgCl2	0.981	795	1.559	N/A	N/A	N/A	T
0.2KCl-0.5LiCl-0.3PbCl2	0.978	687	1.927	N/A	N/A	N/A	T
0.1KCl-0.4LiCl-0.5MnCl2	0.977	806	1.851	N/A	N/A	N/A	T
0.2KCl-0.4LiCl-0.4PbCl2	0.973	654	2.111	N/A	N/A	N/A	T

0.2KCl-0.6LiCl-0.2MnCl2	0.973	751	1.647	N/A	N/A	N/A	T
0.2CaCl2-0.1KCl-0.7LiCl	0.969	777	1.613	N/A	N/A	N/A	T
0.2CaCl2-0.6LiCl-0.2NaCl	0.967	737	1.634	N/A	N/A	N/A	T
0.2KCl-0.5LiCl-0.3MnCl2	0.966	780	1.715	N/A	N/A	N/A	T
0.1KCl-0.6LiCl-0.3MgCl2	0.966	751	1.583	N/A	N/A	N/A	T
0.2KCl-0.7LiCl-0.1MgCl2	0.965	786	1.549	N/A	N/A	N/A	T
0.2KCl-0.4LiCl-0.4MnCl2	0.951	788	1.788	N/A	N/A	N/A	T
0.2KCl-0.6LiCl-0.2MgCl2	0.950	773	1.572	N/A	N/A	N/A	T
0.1KCl-0.5LiCl-0.4MgCl2	0.946	708	1.608	N/A	N/A	N/A	T
0.1KCl-0.5LiCl-0.4NaCl	0.942	793	1.577	N/A	N/A	N/A	T
0.3KCl-0.5LiCl-0.2MnCl2	0.938	707	1.661	N/A	N/A	N/A	T
0.2KCl-0.5LiCl-0.3MgCl2	0.930	739	1.597	N/A	N/A	N/A	T
0.2KCl-0.5LiCl-0.3NaCl	0.927	734	1.573	N/A	N/A	N/A	T
0.2KCl-0.3LiCl-0.5MnCl2	0.924	781	1.869	N/A	N/A	N/A	T
0.3KCl-0.4LiCl-0.3MnCl2	0.923	733	1.730	N/A	N/A	N/A	T
0.1KCl-0.4LiCl-0.5MgCl2	0.922	773	1.633	N/A	N/A	N/A	T
0.1KCl-0.4LiCl-0.5NaCl	0.917	859	1.593	N/A	N/A	N/A	T
0.3KCl-0.5LiCl-0.2MgCl2	0.913	731	1.586	N/A	N/A	N/A	T
0.2KCl-0.4LiCl-0.4MgCl2	0.904	675	1.622	N/A	N/A	N/A	T
0.2KCl-0.4LiCl-0.4NaCl	0.901	809	1.590	N/A	N/A	N/A	T
0.3KCl-0.3LiCl-0.4MnCl2	0.897	751	1.805	N/A	N/A	N/A	T
0.4KCl-0.4LiCl-0.2PbCl2	0.894	595	1.805	N/A	N/A	N/A	T
0.4KCl-0.4LiCl-0.2MnCl2	0.893	683	1.676	N/A	N/A	N/A	T
0.4KCl-0.5LiCl-0.1NaCl	0.892	651	1.567	N/A	N/A	N/A	T
0.1KCl-0.3LiCl-0.6MgCl2	0.887	828	1.659	N/A	N/A	N/A	T
0.3KCl-0.4LiCl-0.3MgCl2	0.886	698	1.610	N/A	N/A	N/A	T
0.3KCl-0.4LiCl-0.3NaCl	0.884	744	1.586	N/A	N/A	N/A	T
0.1AlCl3-0.8LiCl-0.1PbCl2	0.883	824	0.936	N/A	N/A	N/A	T
0.1AlCl3-0.7LiCl-0.2MnCl2	0.881	838	0.938	N/A	N/A	N/A	T
0.1AlCl3-0.8LiCl-0.1NaCl	0.875	879	0.903	N/A	N/A	N/A	T
0.1AlCl3-0.8LiCl-0.1MgCl2	0.874	817	0.905	N/A	N/A	N/A	T
0.4KCl-0.3LiCl-0.3PbCl2	0.872	631	1.966	N/A	N/A	N/A	T
0.1AlCl3-0.7LiCl-0.2PbCl2	0.870	817	0.977	N/A	N/A	N/A	T
0.2KCl-0.3LiCl-0.5MgCl2	0.868	719	1.647	N/A	N/A	N/A	T
0.4KCl-0.3LiCl-0.3MnCl2	0.867	728	1.746	N/A	N/A	N/A	T
0.1AlCl3-0.6LiCl-0.3MnCl2	0.867	845	0.960	N/A	N/A	N/A	T
0.4KCl-0.4LiCl-0.2MgCl2	0.866	673	1.599	N/A	N/A	N/A	T
0.2KCl-0.3LiCl-0.5NaCl	0.865	872	1.606	N/A	N/A	N/A	T
0.4KCl-0.4LiCl-0.2NaCl	0.865	682	1.583	N/A	N/A	N/A	T
0.5KCl-0.4LiCl-0.1MnCl2	0.860	635	1.625	N/A	N/A	N/A	T
0.5KCl-0.4LiCl-0.1PbCl2	0.857	700	1.683	N/A	N/A	N/A	T
0.1AlCl3-0.7LiCl-0.2NaCl	0.853	879	0.908	N/A	N/A	N/A	T
0.1AlCl3-0.6LiCl-0.3PbCl2	0.851	820	1.022	N/A	N/A	N/A	T
0.3KCl-0.3LiCl-0.4NaCl	0.847	816	1.603	N/A	N/A	N/A	T
0.5KCl-0.4LiCl-0.1MgCl2	0.846	662	1.588	N/A	N/A	N/A	T

0.5KCl-0.4LiCl-0.1NaCl	0.845	764	1.580	N/A	N/A	N/A	T
0.5KCl-0.3LiCl-0.2PbCl2	0.831	667	1.823	N/A	N/A	N/A	T
0.1AlCl3-0.6LiCl-0.3NaCl	0.828	879	0.914	N/A	N/A	N/A	T
0.4KCl-0.3LiCl-0.3NaCl	0.827	748	1.600	N/A	N/A	N/A	T
0.1AlCl3-0.5LiCl-0.4PbCl2	0.827	807	1.072	N/A	N/A	N/A	T
0.1AlCl3-0.4LiCl-0.5PbCl2	0.792	777	1.127	N/A	N/A	N/A	T
0.2AlCl3-0.7LiCl-0.1MnCl2	0.703	887	0.650	N/A	N/A	N/A	T
0.2AlCl3-0.7LiCl-0.1NaCl	0.691	879	0.643	N/A	N/A	N/A	T
0.2AlCl3-0.7LiCl-0.1PbCl2	0.690	840	0.659	N/A	N/A	N/A	T
0.2AlCl3-0.7LiCl-0.1MgCl2	0.689	842	0.644	N/A	N/A	N/A	T
0.2AlCl3-0.1CaCl2-0.7LiCl	0.678	891	0.648	N/A	N/A	N/A	T
0.2AlCl3-0.6LiCl-0.2NaCl	0.660	879	0.645	N/A	N/A	N/A	T
0.2AlCl3-0.6LiCl-0.2PbCl2	0.657	823	0.679	N/A	N/A	N/A	T
0.2AlCl3-0.5LiCl-0.3PbCl2	0.616	797	0.701	N/A	N/A	N/A	T
0.3AlCl3-0.6LiCl-0.1MnCl2	0.532	895	0.503	N/A	N/A	N/A	T
0.3AlCl3-0.6LiCl-0.1NaCl	0.522	879	0.499	N/A	N/A	N/A	T
0.3AlCl3-0.6LiCl-0.1MgCl2	0.520	816	0.500	N/A	N/A	N/A	T
0.3AlCl3-0.6LiCl-0.1PbCl2	0.516	800	0.509	N/A	N/A	N/A	T