Ph.D. Preliminary Oral Exam

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Radhika Naik
Department of Chemistry
Oregon State University
Advisor: Dr. Walter Loveland

- **Thesis Research Proposal**: Determination of P_{CN} for cold fusion reaction ^{208}Pb (^{50}Ti, 2n) ^{256}Rf

- **Outside Topic Proposal**: A Pilot Study of Fusion of Halo Nucleus: ^{11}Li + ^{70}Zn

Thesis Research Proposal

Determination of P_{CN} for cold fusion reaction $^{208}Pb(^{50}Ti, 2n)^{256}Rf$

- ‘Cold’ fusion which involves Pb or Bi target and a relatively heavier projectile, like Ti. The compound nuclei produced have an excitation energy of around 10-15 MeV.

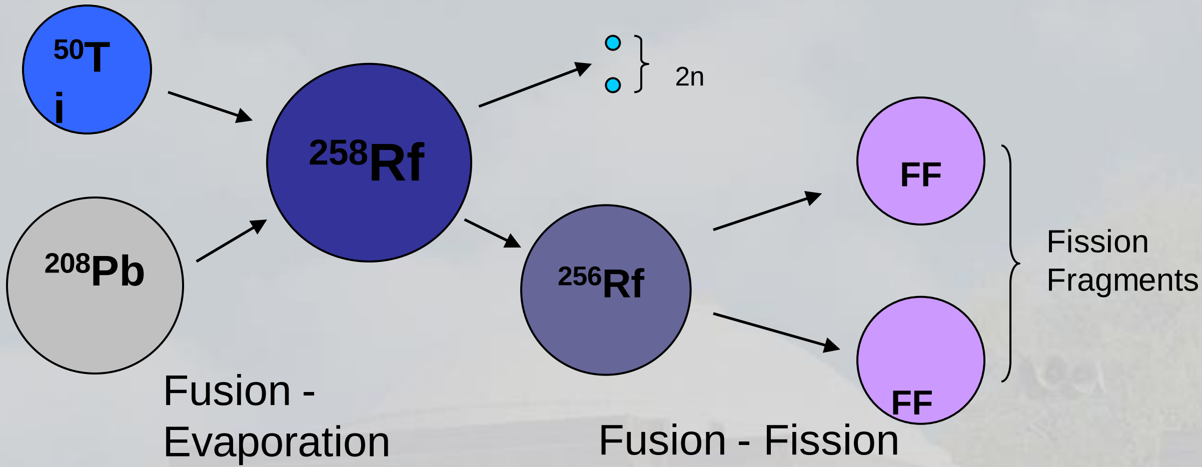
- Cross section for producing a heavy nucleus in a heavy ion reaction is

$\sigma_{ER} = \sigma_C * P_{CN} * W_{SUR}$

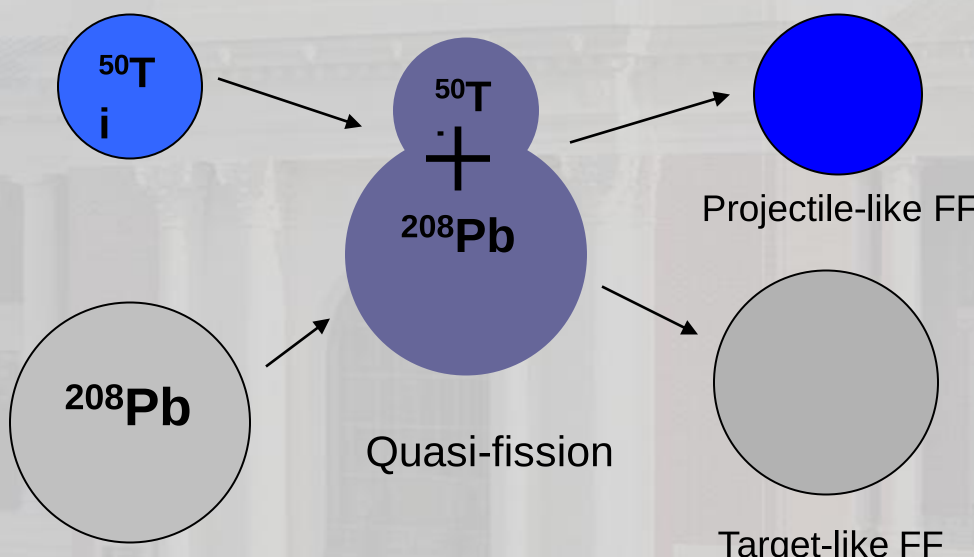
where σ_C - Capture cross section

P_{CN} - Probability of formation of compound nucleus

W_{SUR} - Survival probability of the excited nucleus

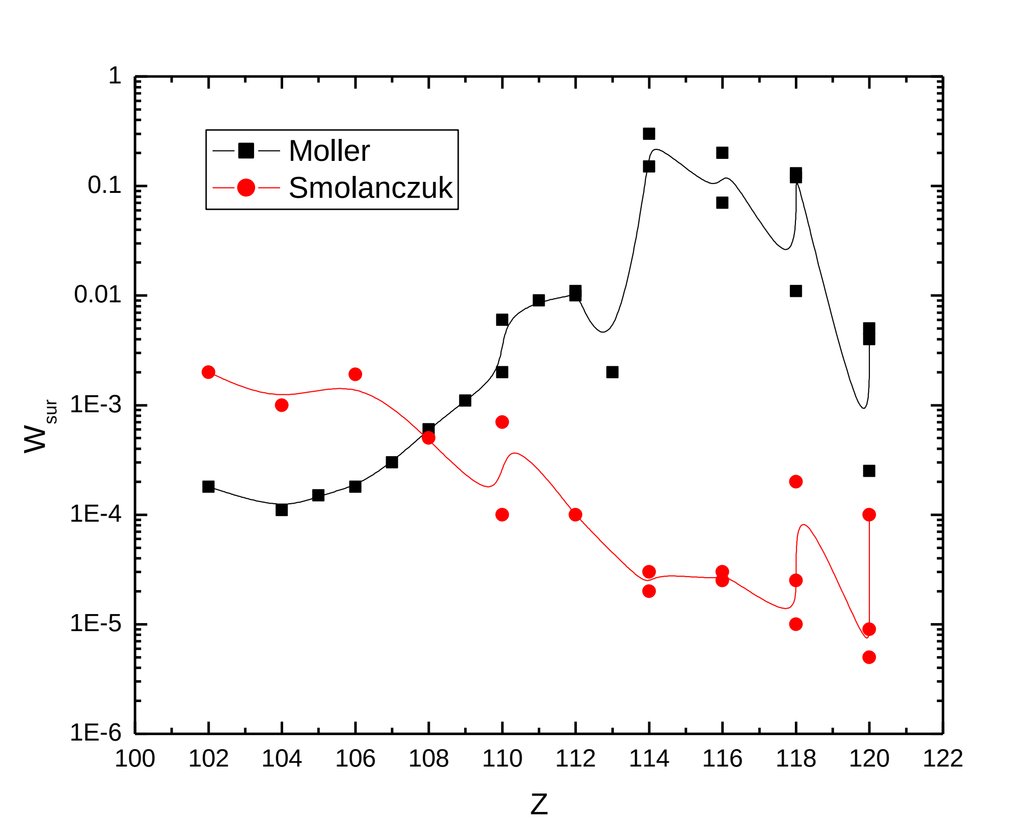


50Ti
208Pb
258Rf
2n
256Rf
FF
FF
Fission Fragments
Fusion - Evaporation
Fusion - Fission

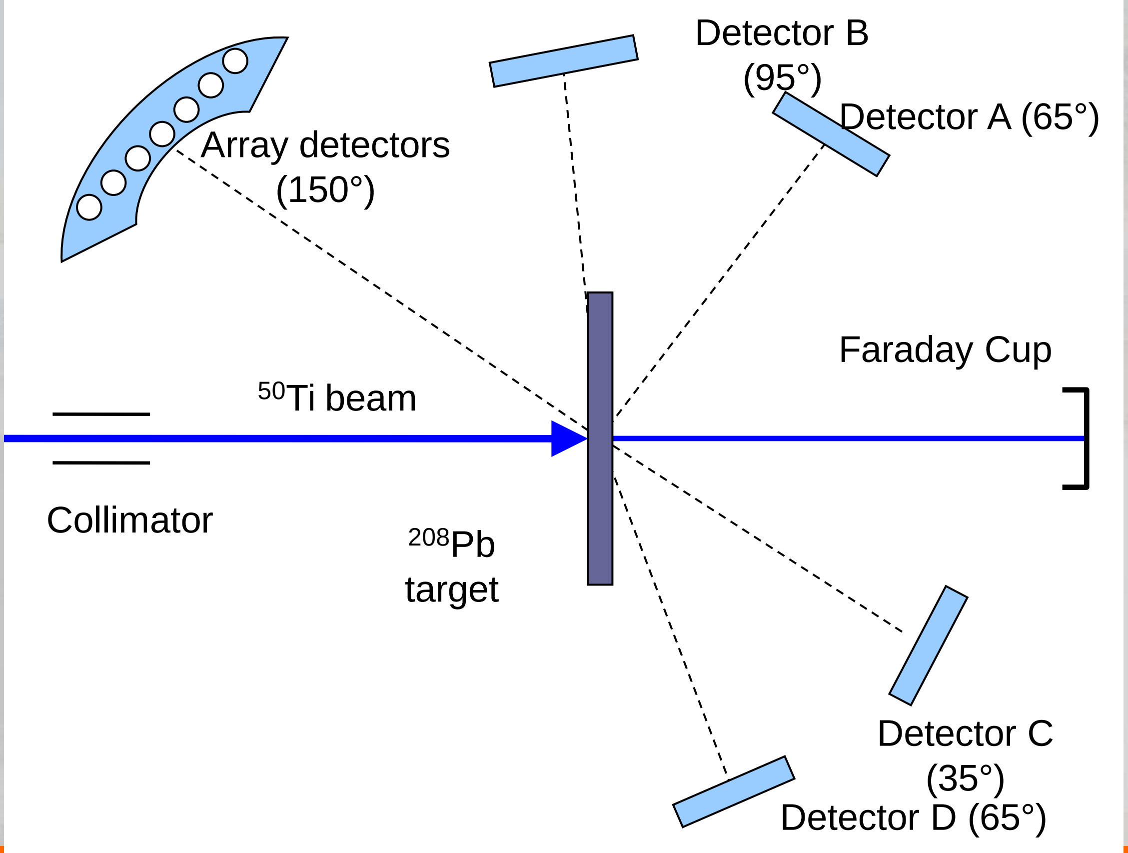


50Ti
208Pb
50Ti + 208Pb
Projectile-like FF
Target-like FF
Quasi-fission

● The values of W_{sur} based on two different methods by two groups of theoreticians differ by more than an order of magnitude for most of the heavy elements and show an opposite trend with increasing Z.



• An experiment to study reaction ^{208}Pb (^{50}Ti, 2n)^{256}Rf to determine its P_{CN} was done at the ATLAS facility of Argonne National Laboratory (ANL). A ^{50}Ti beam struck the ^{208}Pb target at five different beam energies, 230, 233, 238, 243 and 253 MeV.



Schmitt-Kiker-Williams Calibration Method

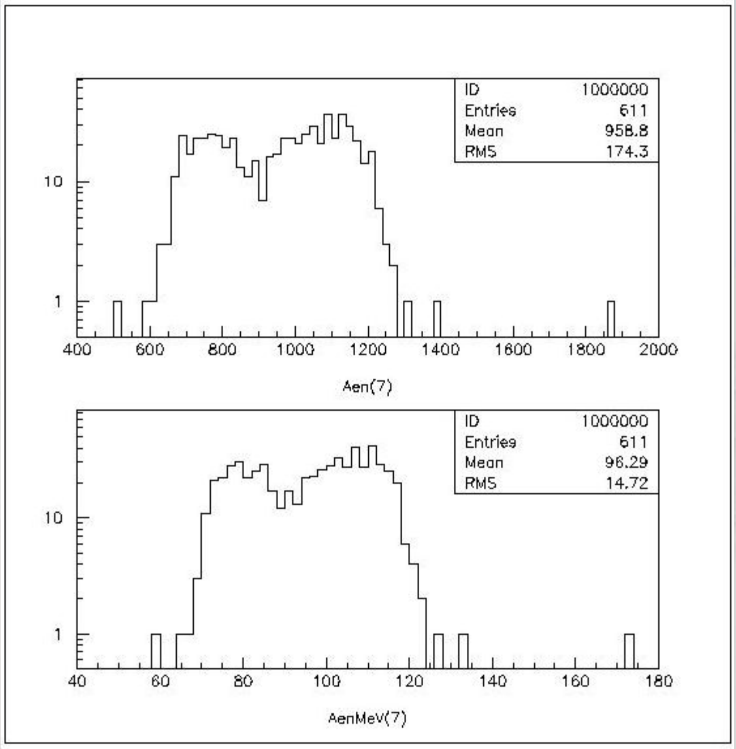
$a = 24.0203/(P_L - P_H)$ $b = 89.6083 – a*P_L$

$a' = 0.03574/(P_L - P_H)$ $b' = 0.1370 – a'*P_L$

P_L – Pulse height for light fragment peak

P_H - Pulse height for heavy fragment peak

$E_{(MeV)} = [a+(a'*M_{(amu)})]*P+[b+(b'*M_{(amu)})]$



- Angular distribution (strips of DSSD's and individual SB detectors)
- Energy loss calculations (SRIM, UPAK)
- Elastic Scattering (RUTH, experimental data)

Time Calibration

$$\beta = \sqrt{2\,E / m\,c^2}$$

$$\text{Time (ns)} = \text{Path}/\beta * c$$

E – Energy of elastically scattered particle

c – Speed of light (29.98 cm/ns)

m – Mass of the beam particle (50 amu)

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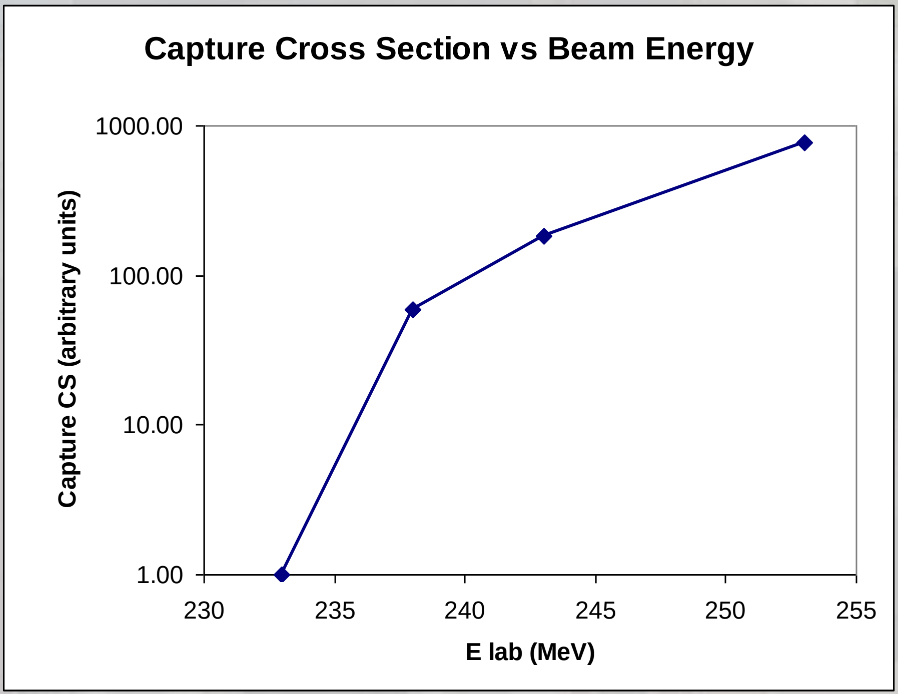
Capture cross section

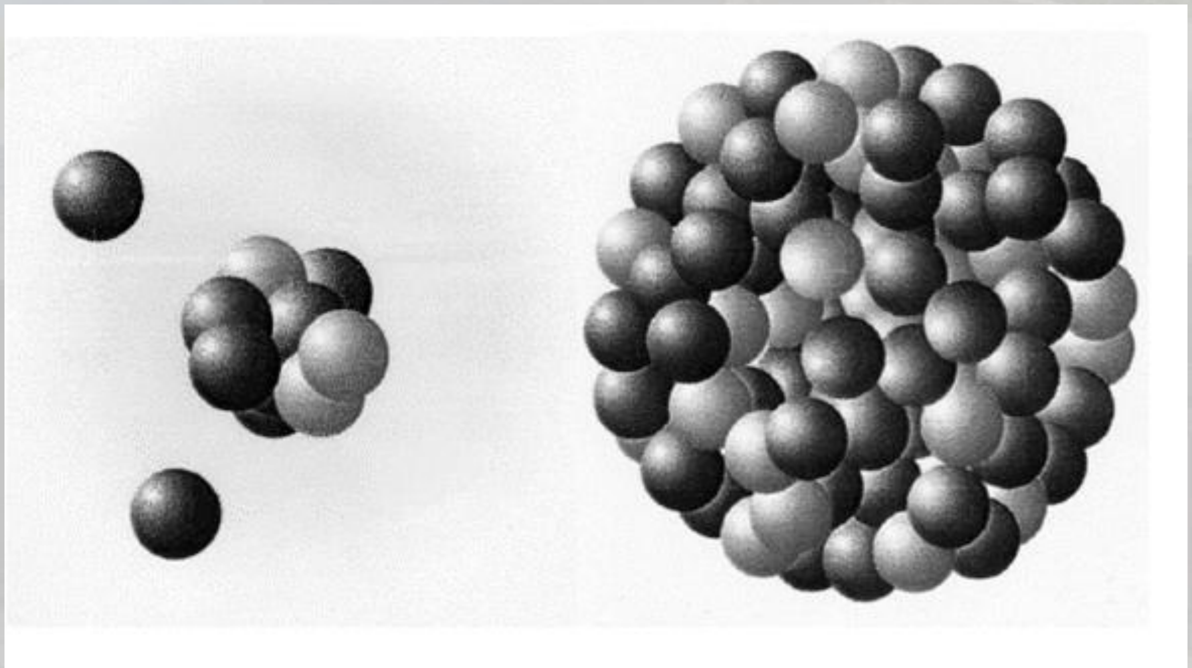
$$\sigma_c = \frac{\text{Number of fission events}}{\text{(Number of total particles in the run x Number of atoms in the target)}} \text{ x Various correction factors}$$



Outside Topic Proposal

A Pilot Study of Fusion of Halo Nucleus: $^{11}Li + ^{70}Zn$

- Some of the n-rich nuclei, especially the lighter ones, tend to show a peculiar nuclear structure and hence are called ‘Halo nuclei’.
- The ^{11}Li nucleus is ^{9}Li core with two halo neutrons and has a radius which is almost equal to that of ^{208}Pb!



Borromean Rings

- ^{11}Li is also called a "Borromean Nucleus"
- Symbol of 'strength in unity'
- Cut one off , remaining two come apart
- True for ^{11}Li, if one neutron comes off, it breaks up

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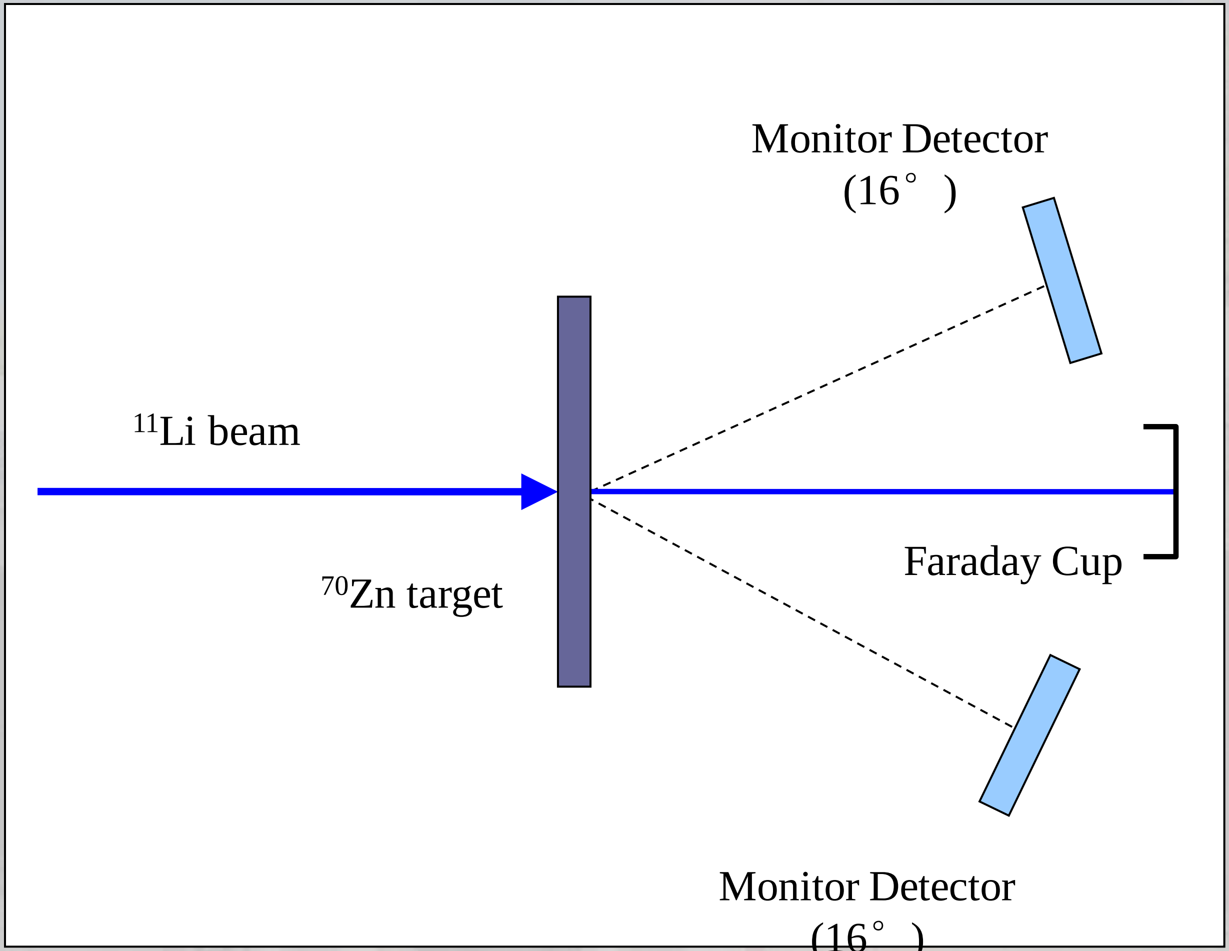
Fusion with Halo nuclei

Theoretical contradictions	Experimental contradictions
•Enhancement near or sub-barrier due to lower Coulomb barrier and Soft Dipole Mode	•Enhancement : ^{11}Be (Munich) : ^{6}He (Dubna)
•Lowering above barrier due to breakup of nucleus into 'core' and separated 'halo nucleons'	•Lowering : ^{11}Be (RIKEN) : ^{6}He (Kolata et. al.)

- To measure the fusion excitation function for the reaction of $^{9/11}Li$ with ^{70}Zn for 12-18 MeV beam, at TRIUMF, Canada.



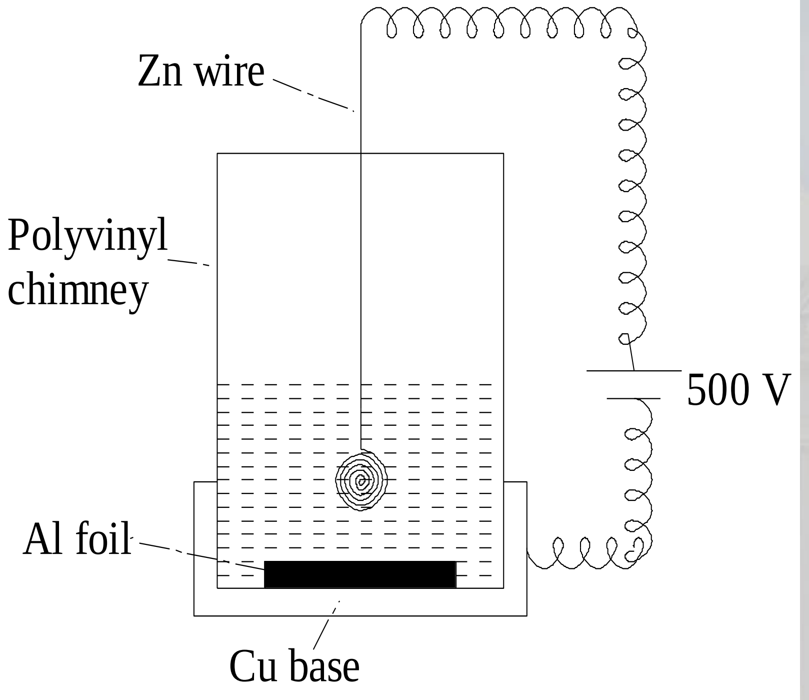
Preparing Zn targets by electroplating

- Target area density 1mg/cm^2

- Electrolyte : $ZnSO_4.7H_2O$, $Al_2(SO_4)_3.18H_2O$, NH_4Cl

- Zn wire : anode, Al foil : cathode

- $ZnSO_4 \rightarrow Zn^{2+} + SO_4^{2-}$
  Zn^{2+} (electrolyte) + $2e^- \rightarrow Zn$
  Zn (zinc wire) $\rightarrow Zn^{2+} + 2e^-$
  $Zn^{2+} + SO_4^{2-} \rightarrow ZnSO_4$



EVR formation

The EVR's expected to be formed based on PACE4,

- $^{9}Li + ^{70}Zn \rightarrow ^{79}As \rightarrow$ ***^{76}As*** $+ 3n$
- $^{11}Li + ^{70}Zn \rightarrow ^{81}As \rightarrow$ ***^{77}As*** $+ 4n$

  $^{11}Li + ^{70}Zn \rightarrow ^{81}As \rightarrow$ ***^{77}Ge*** $+4n + p$

Extraction of As and Ge from the irradiated target and their separation

- Irradiated target was dissolved in HCl, 1 ml each of the As and Ge standard carriers were added to it.
- AsI_3 and GeI_4 were formed with Hydriodic Acid (HI) added.
- They were then extracted with Chloroform ($CHCl_3$), AsI_3 first and then GeI_4.
- H_2S passed through them, As_2S_3 and GeS_2 formed, filtered, dried and counted.
- 100% yield for both As and Ge.

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Experiment run details

- The ^{9}Li beam was run at 15.4, 13.5 and 11.5 MeV and the ^{11}Li was run at 17.5 MeV.
- The runs with ^{9}Li beam were approximately 10 hour runs and that with the ^{11}Li was 40 hour run.
- Target foil was counted for gammas using a Germanium (Ge) detector and a Sodium Iodide (NaI) detector.
- The separated As and Ge fractions were counted individually with a beta and a gamma counter.

Results from preliminary analysis

$\sigma_{fus} = A / n \times \Phi \times (1-e^{-\lambda t_i}) \times (e^{-\lambda t_d})$

where, A – Activity

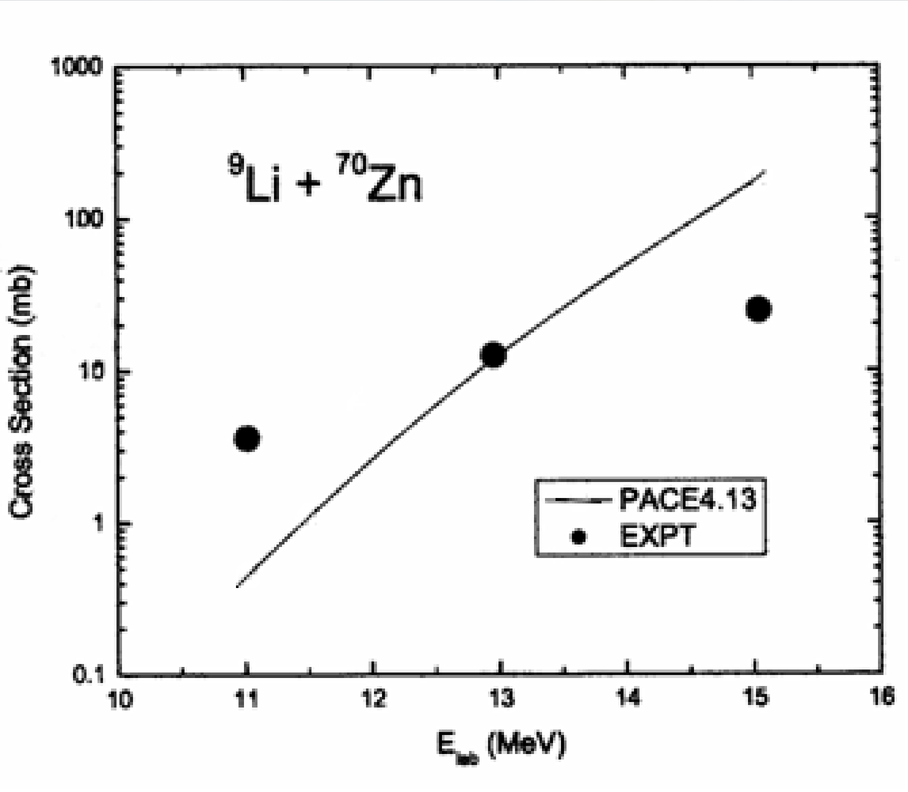
n - # of target atoms

Φ – Beam flux

λ – Decay constant

t_i – Duration of irradiation

t_d – Time after EOB when counting was started



Thank you!

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Acknowledgements

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