Title: Using Antimatter to Aid in the Design of Safer more Efficient Nuclear Power Plants

Date: Jul 21, 2011 11:30 AM

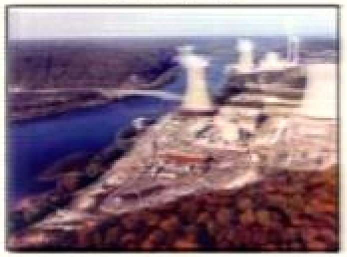
URL: http://pirsa.org/11070079

Abstract: We are doing research on the chemical reaction of the hydrogen atom with water under sub- and supercritical conditions. Supercritical water is water above the critical point (373.9 C and 220.6 bar). This reaction is one of the most important reactions in the next generation of nuclear reactors called Gen IV, where supercritical water will be used as a coolant. We have been studying this reaction by the SR experimental technique. SR is the only technique that is able to work under these extreme conditions to provide kinetics data and it can be a billion times more sensitive than other techniques. TRIUMF, the particle accelerator in Vancouver is the facility that we used to collect data.

Gen-IV: Nuclear Reactors

Generation I

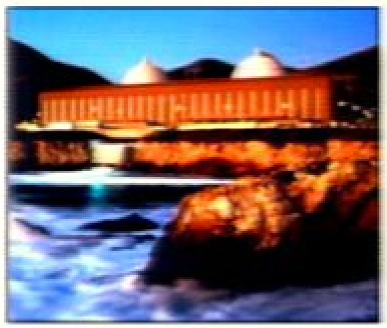
Early Prototype Reactors



- Shippingport
- Dresden, Fermi I
- Magnox

Generation II

Commercial Power Reactors



- LWR-PWR, BWR
- CANDU
- AGR

Generation III

Advanced LWRs

- ABWR
- System 80+

Generation III +

Evolutionary Designs Offering Improved Economics for Near-Term Deployment

Generation IV

- Highly Economical
- Enhanced Safety
- Minimal Waste
- Proliferation Resistant

Gen III | Gen III+ | Gen IV

1950 1960 1970 1980 1990 2000 2010 2020 2030

Image is adapted from:
U.S. DOE Nuclear Energy Research Advisory Committee and the Generation IV International Forum, *A Technology Roadmap for Generation IV Nuclear Energy Systems*, p. 5, December 2002.

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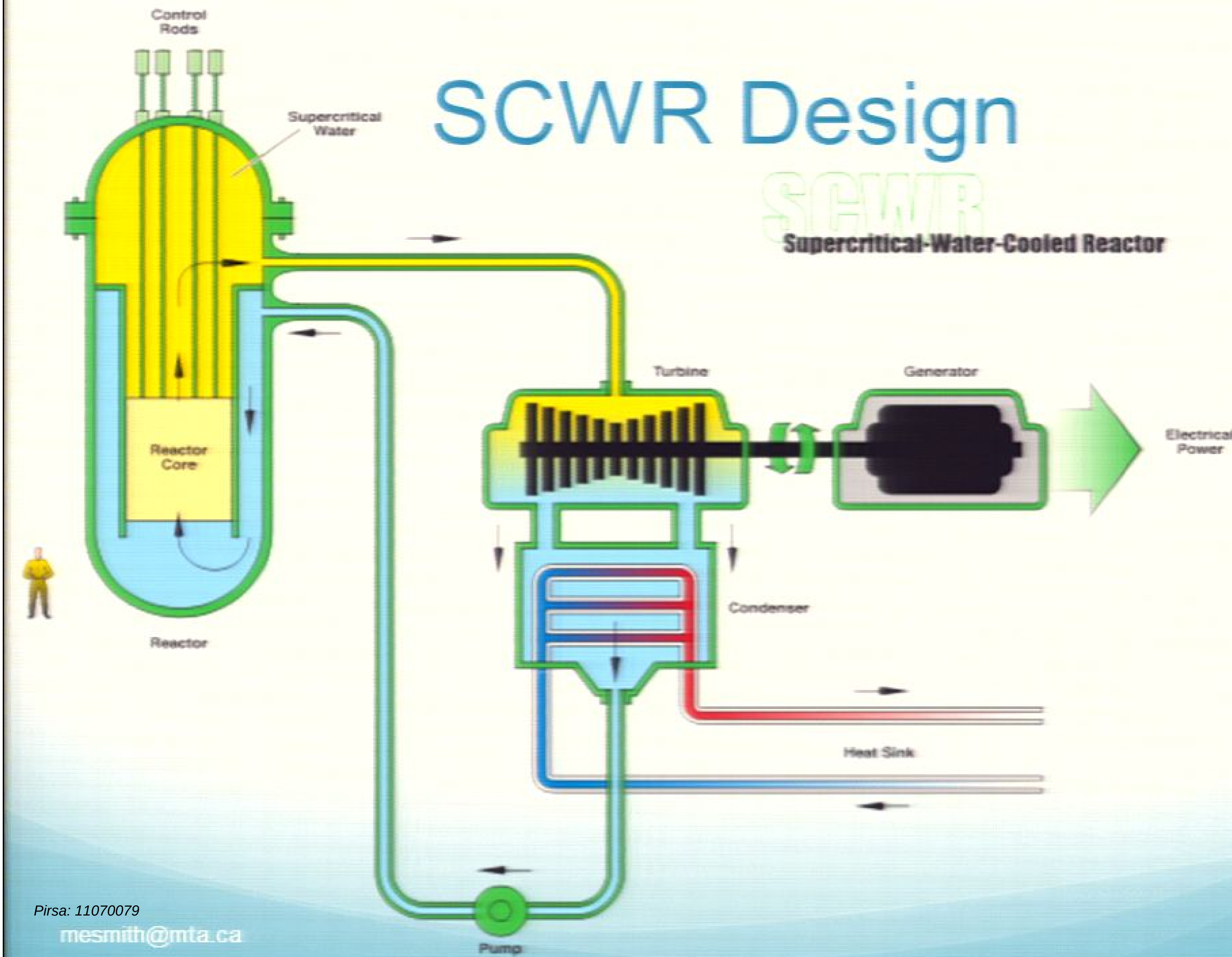
SCWR Design



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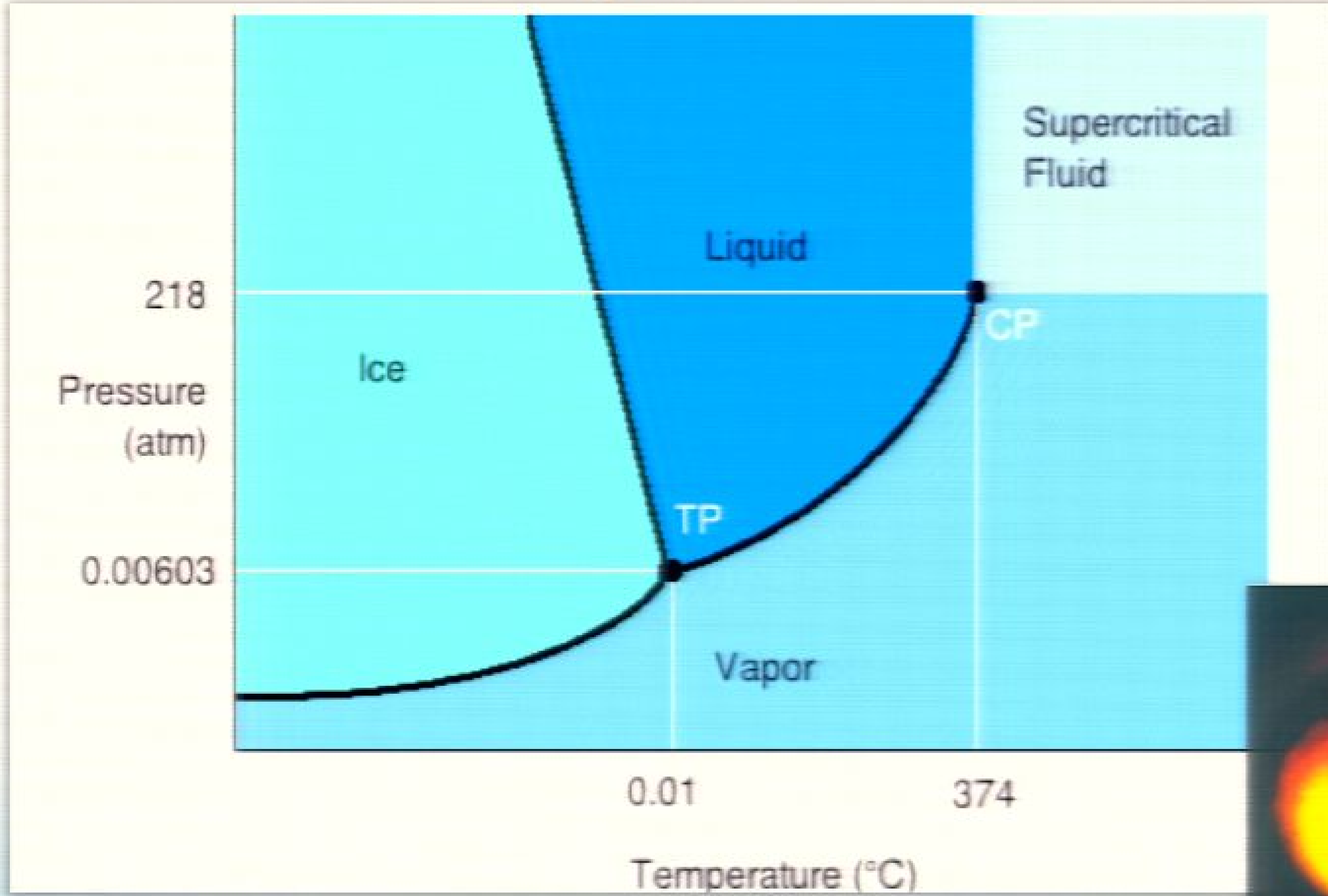
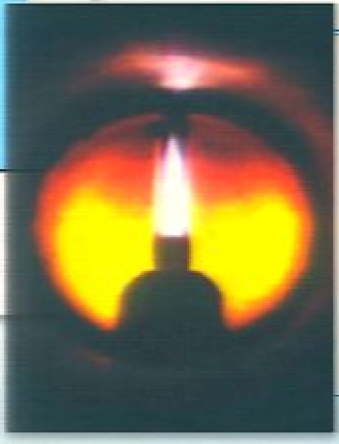
Gen-IV: Sub- and Supercritical Water



<u>Unique Properties</u>

- Liquid/Gas
- "Tuneable"
  - Density
  - Viscosity
  - Dielectric Constant
  - Degree of Hydrogen Bonding



<u>Organic Solvent</u>

- W. Schilling and E. U. Franck, Ber. Bunsenges. Phys. Chem. 92 (1998) 631

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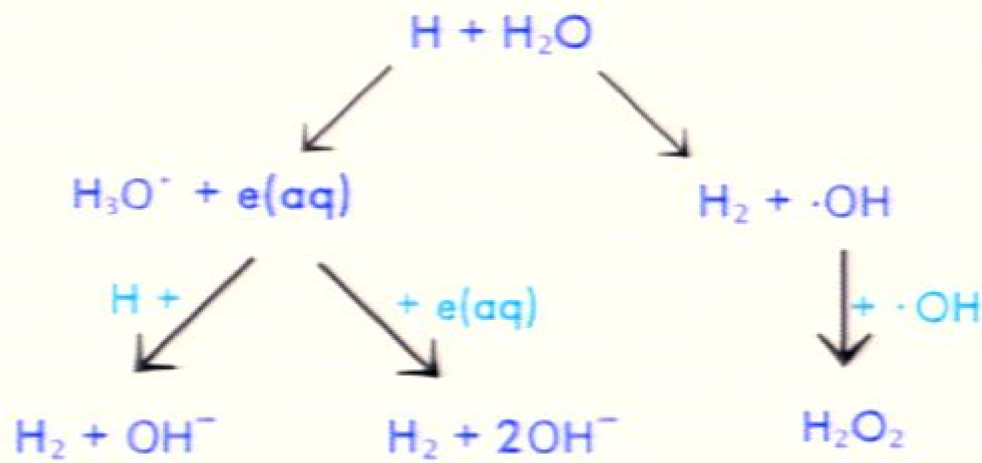
Gen-IV: Reactor Chemistry

- Temperature dependence
- Pressure dependence
- Most important reaction for safety studies
  - Corrosion
    - Safety
    - Economics
    - Sustainability



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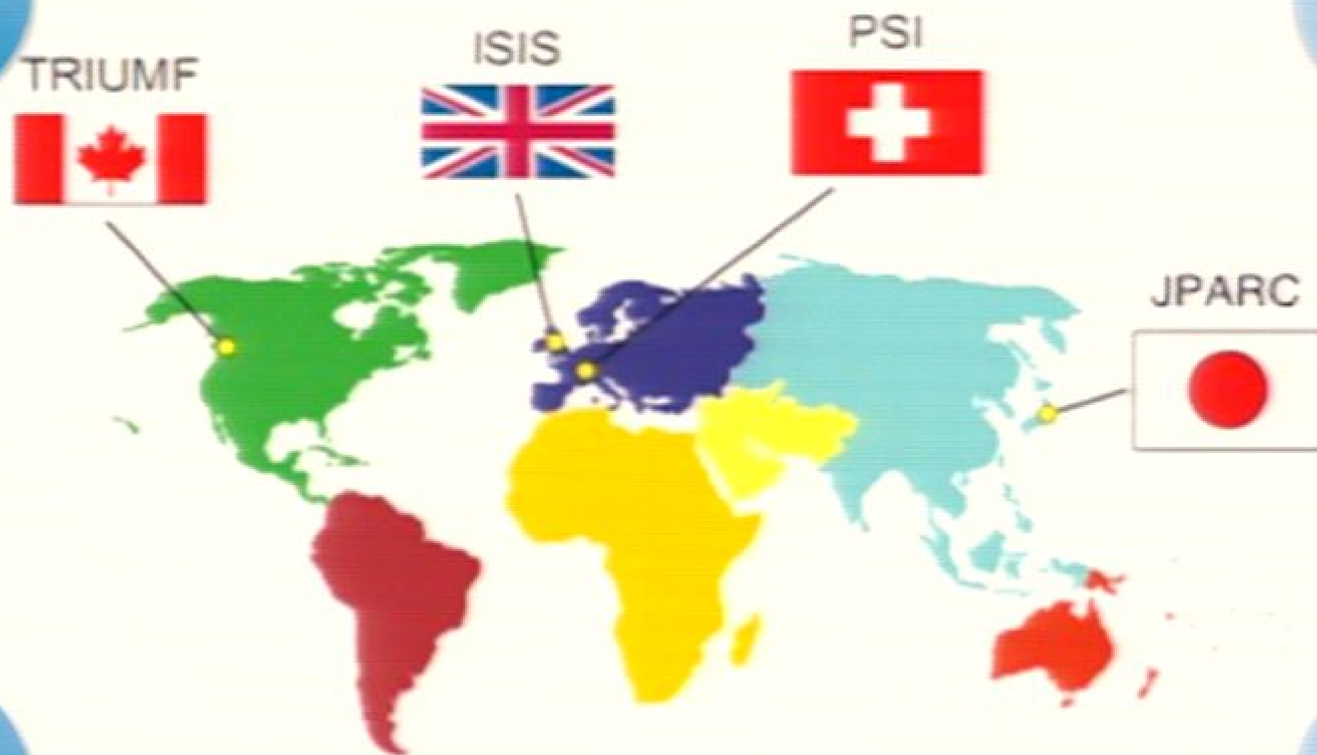
μSR

Muon spin resonance (relaxation, and/or rotation)

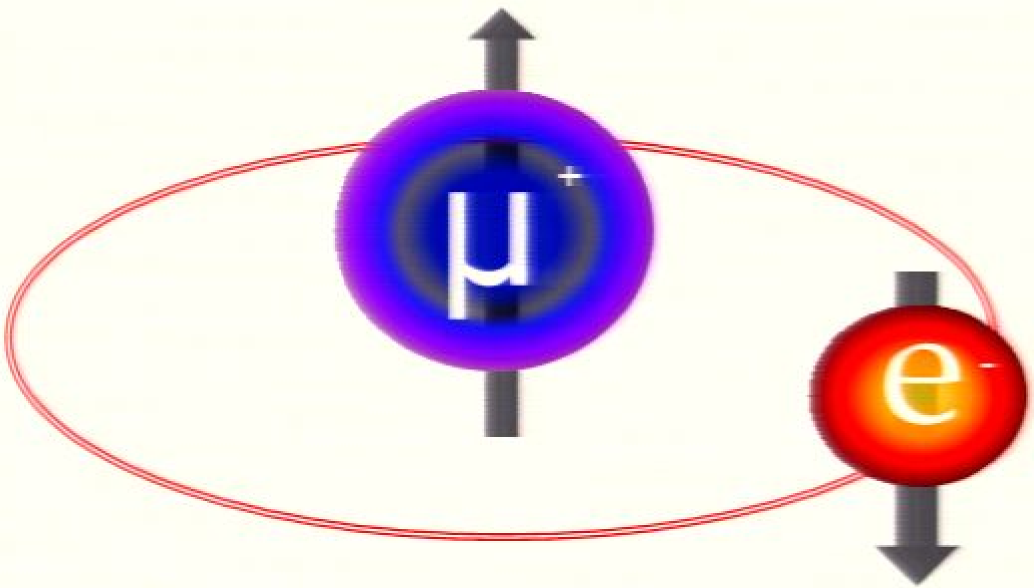
Used under extreme conditions



Orders of magnitude more sensitive than comparable techniques

Clean

μSR: Muons and Muonium



- Antimuons:
  - Properties:
    - Positive charge
    - Life time: 2.2 micro seconds (μs)
      - 0.00000022 seconds!
- Muonium:
  - Muon antiparticle and orbiting electron
  - Light isotope of hydrogen
  - Reduced mass: 99.5% of H

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TF-μSR

Injection Line
- H_2 molecules are converted into H-

Cyclotron
- Accelerates gaining energy
- Metal foil strips charge

Beamline
- Collided with carbon creates pion
- Quadrapoles and Bending magnets
- Collimator

Experiment
- Experimenter sets up a magnetic field
- Detectors start and stop electronic clock

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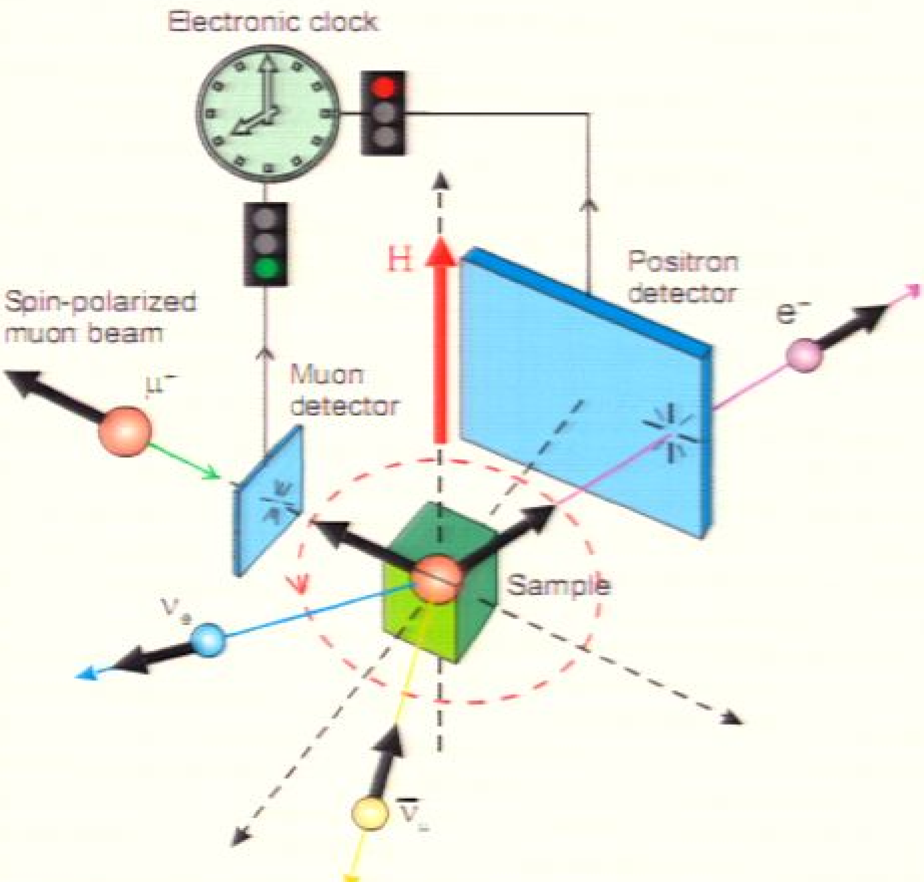
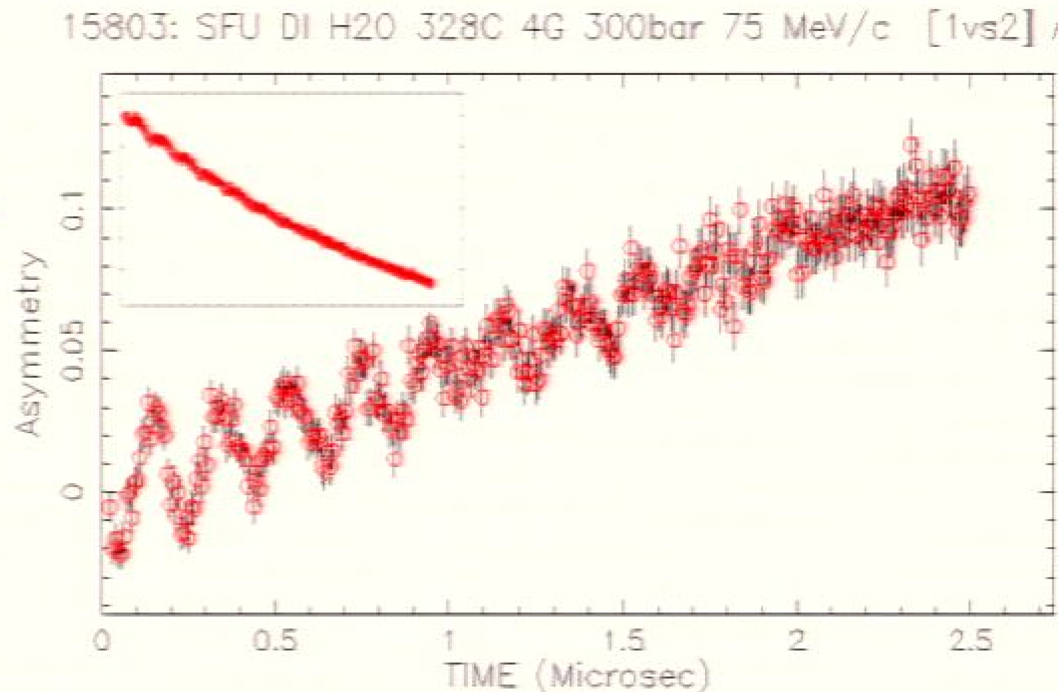
TF-μSR





$$A(t) = A_{\mathrm{Mu}} e^{-\lambda_{exp} t} \cos(\omega_{\mathrm{Mu}} t - \phi_{\mathrm{Mu}}) + A_D \cos(\omega_D t - \phi_D)$$

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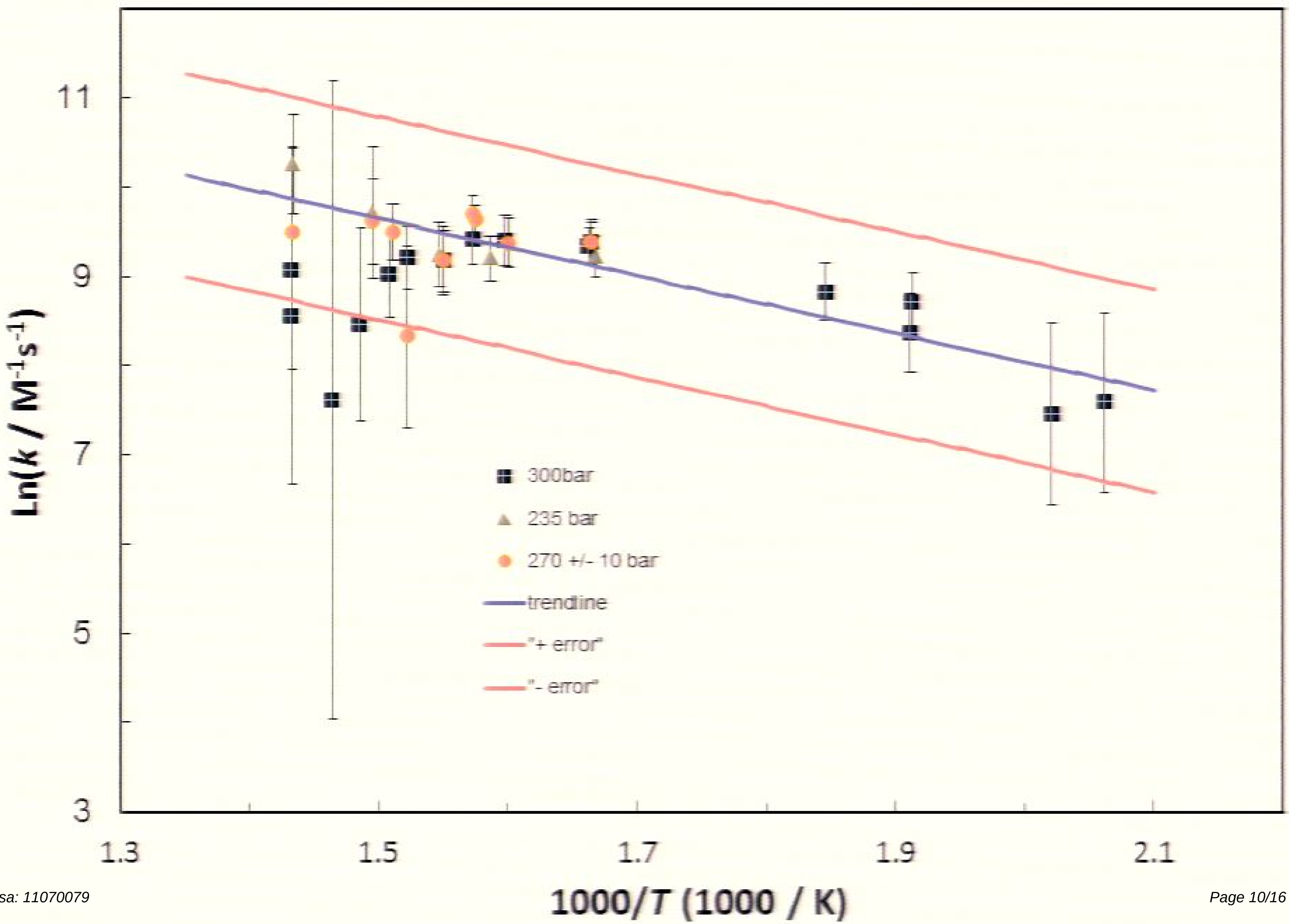
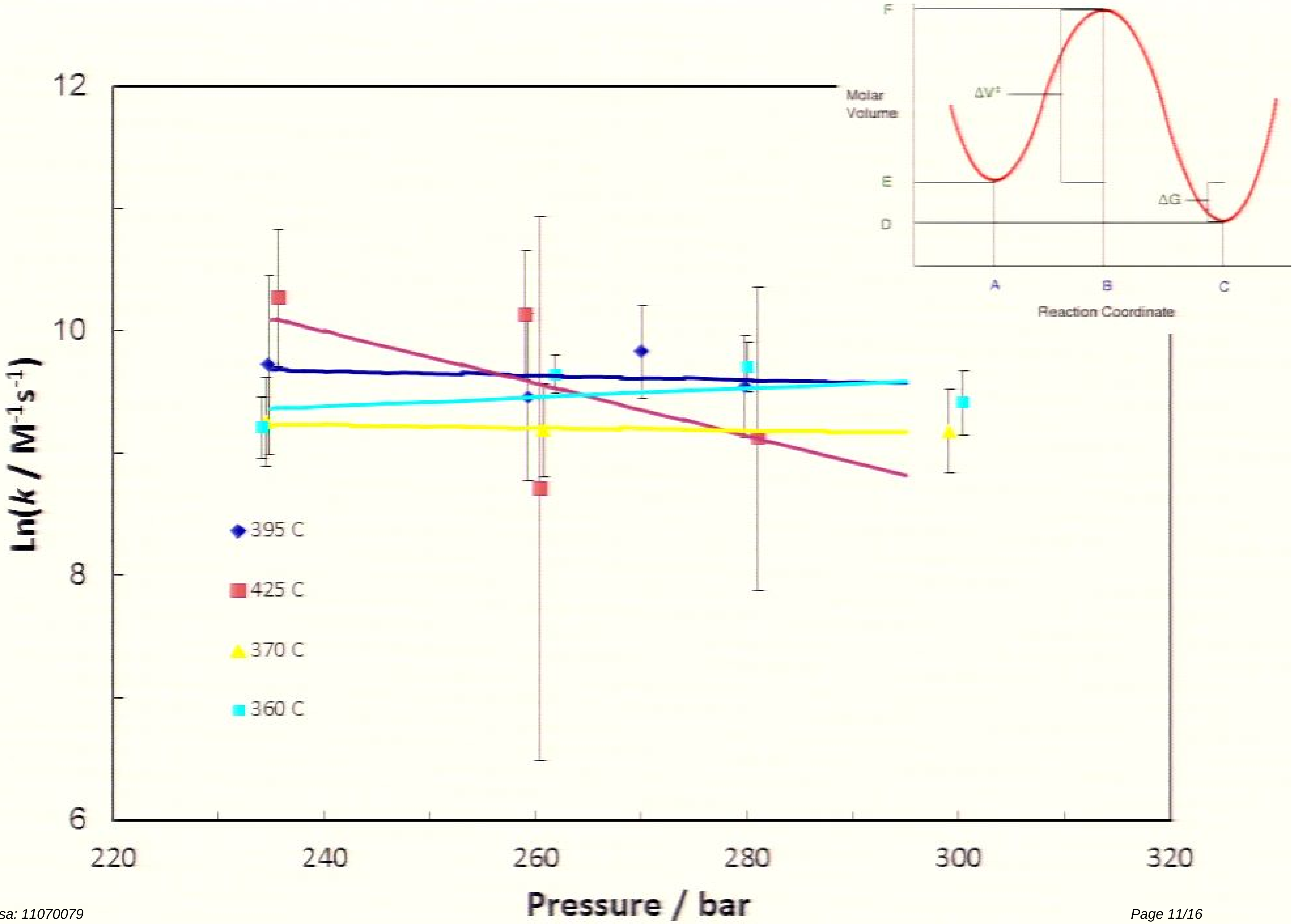


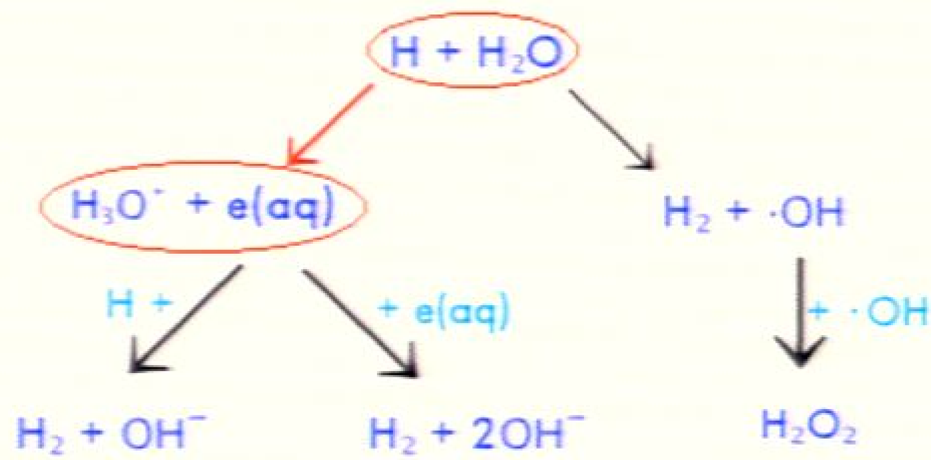
11
9
7
5
3
1.3
1.5
1.7
1.9
2.1
Ln(k / M-1s-1)
1000/T (1000 / K)
300bar
235 bar
270 +/- 10 bar
trendline
"+ error"
"- error"



Molar Volume
F
E
D
ΔV‡
ΔG
A
B
C
Reaction Coordinate
12
10
8
6
220
240
260
280
300
320
Ln(k / M^{-1}s^{-1})
Pressure / bar
395 C
425 C
370 C
360 C

Experimental: Results

Activation Energy	$kJmol^{-1}$	±
	18	5
Activation Enthalpy	$kJmol^{-1}$	±
325 C	8	5
Activation Entropy	$Jmol^{-1}K^{-1}$	±
	-93	8
Activation Volumes	cm^3mol^{-1}	±
360 C	-191	1.0
370 C	58.25	0.04
395 C	99.2	0.6
425 C	1250	15



Conclusions and Future Research

- Conclusions:
  - Lots of H_2 produced from 2 reactions
  - Water as coolant may need to be pure
- Future research:
  - Higher temperatures up to 650 C
  - Lower pressures
  - $HO\bullet + \bullet OH \rightarrow H_2O_2$

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- NRC- National Research Council Canada
- ACEnet- Atlantic Computational Excellence Network
- Professor Ghandi and the Family Antimatters Group
- Women in Physics organizers

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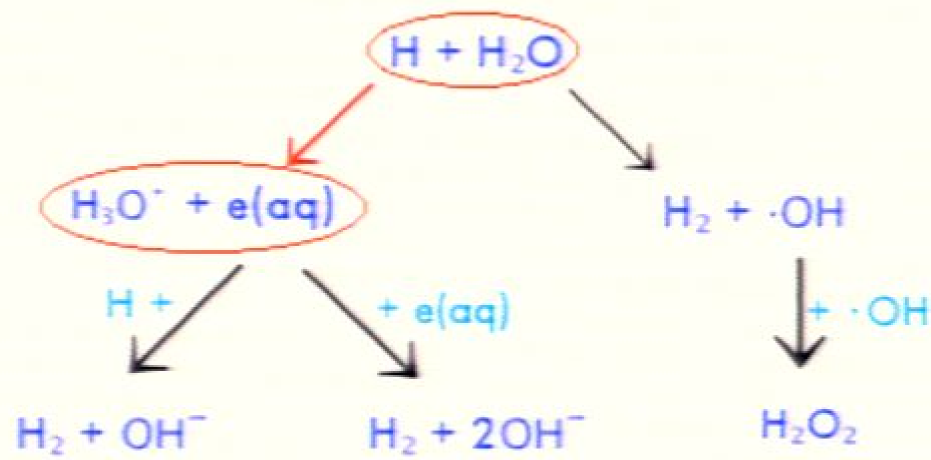

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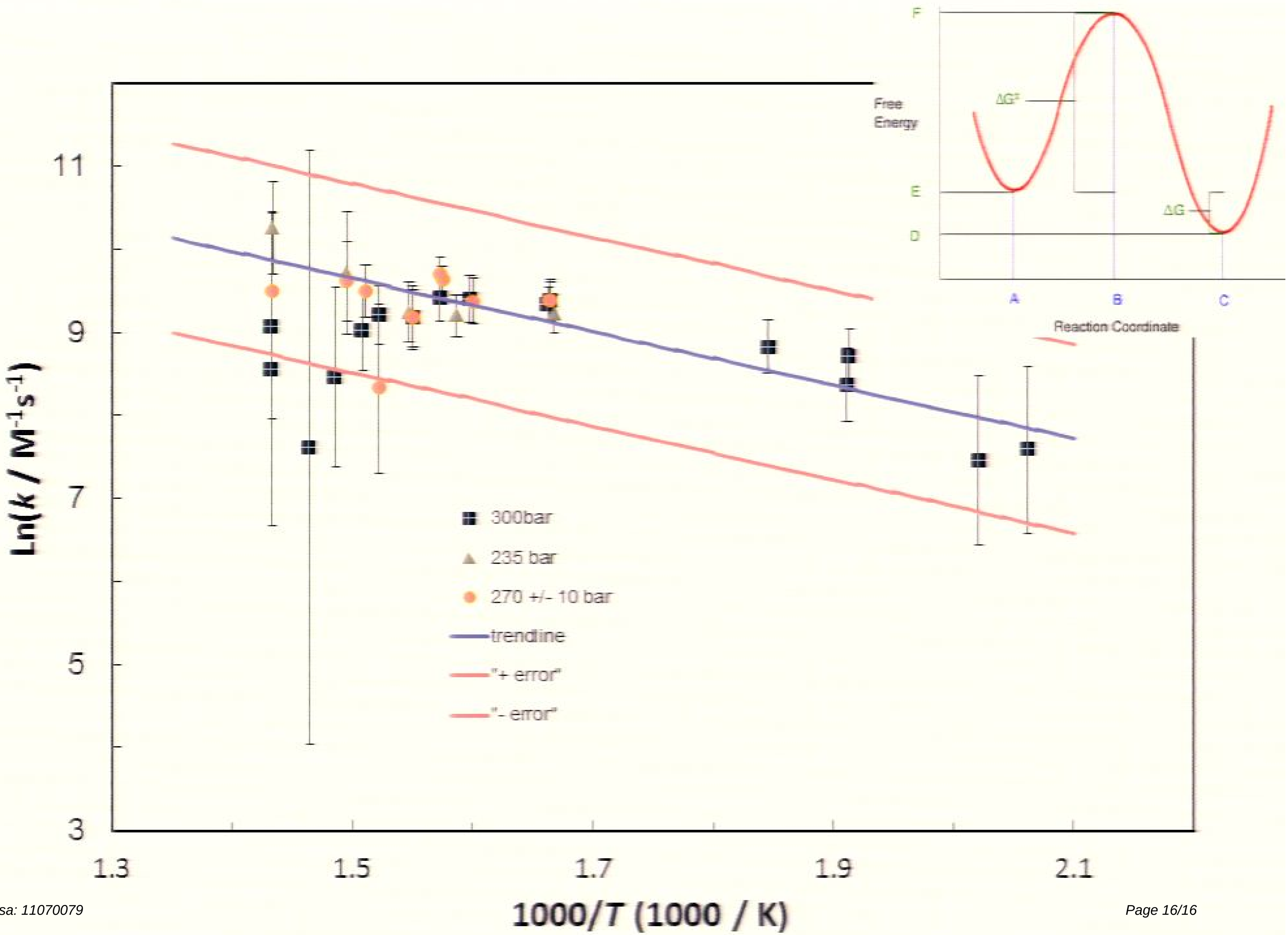
Ln(k / M-1s-1)
11
9
7
5
3
1.3
1.5
1.7
1.9
2.1
1000/T (1000 / K)
300bar
235 bar
270 +/- 10 bar
trendline
"+ error"
"- error"
Free Energy
F
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ΔG
A
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C
Reaction Coordinate