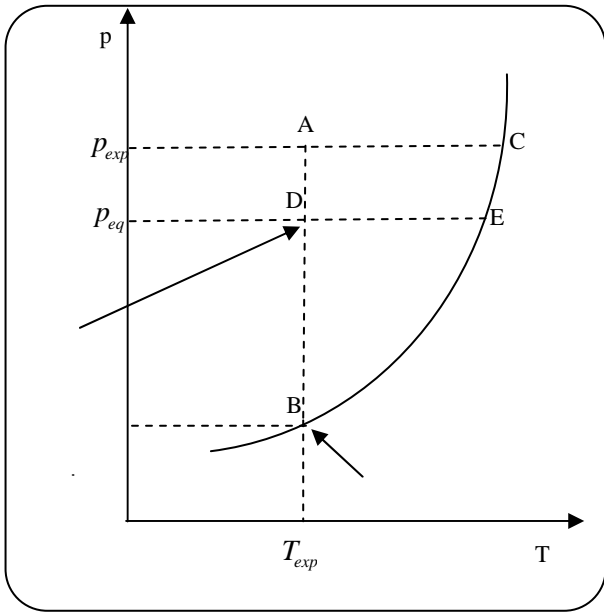


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**KEY WORDS:** *Helmholtz free energy, Driving force, Formation kinetics, Gas hydrate.*



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$N_P$

+

$n_T$

(

$\sum_j x_{ij} \mu_{ij}$

A

[ ]

( ) B

$\Delta A_{initial}$

$$\Delta A_{initial} = A_{max} - A_{min} = \quad ( )$$

$$A_{initial} - A_{eq} = A_{point A} - A_{point B}$$

$\Delta A$

:

$$\Delta A = n_T \left[ \sum_{i=1}^{N_c} \sum_{j=1}^{N_p} x_{ij} \mu_{ij} - \sum_{i=1}^{N_c} \sum_{j=1}^{N_p} x_{ij}^e \mu_{ij}^e \right] \quad ( )$$

$$\Delta A = n_T \left[ \sum_{i=1}^{N_c} \sum_{j=1}^{N_p} X_{ij}(T_{exp}, p) \mu_{ij}(T_{exp}, p) - \right. \quad ( )$$

$$\left. \sum_{i=1}^{N_c} \sum_{j=1}^{N_p} X_{ij}^e(T_{exp}, p_{eq}) \mu_{ij}^e(T_{exp}, p_{eq}) \right]$$

$$A = \sum_{j=1}^{N_p} \sum_{i=1}^{N_c} n_{ij} \mu_{ij} \quad ( )$$

$$A = n_T \sum_{i=1}^{N_c} \sum_{j=1}^{N_p} x_{ij} \mu_{ij} \quad ( )$$

$N_C$

...

$$\Delta A = n_T \sum_{i=1}^{N_c} \sum_{j=1}^{N_p} (x_{ij}(p) \mu_{ij}^\circ + x_{ij}(p) RT \ln f_{ij}) - n_T \sum_{i=1}^{N_c} \sum_{j=1}^{N_p} (x_{ij}^e \mu_{ij}^\circ + x_{ij}^e RT \ln f_{ij}^e) \quad (1)$$

$$\mu_{ij} = \mu_{ij}^\circ + RT \ln f_{ij} \quad (2)$$

(Valderama - Petal & Teja) VPT

$$\Delta A = n_T \left[ \sum_{i=1}^{N_c} \sum_{j=1}^{N_p} (x_{ij}(p) \mu_{ij}^\circ + x_{ij}(p) RT \ln f_{ij}) - \sum_{i=1}^{N_c} \sum_{j=1}^{N_p} (x_{ij}^e \mu_{ij}^\circ + x_{ij}^e RT \ln f_{ij}^e) \right] \quad (3)$$

$$\Delta A = n_T \sum_{i=1}^{N_c} \sum_{j=1}^{N_p} \left[ (x_{ij}(p) - x_{ij}^e) \mu_{ij}^\circ + (x_{ij}(p) RT \ln f_{ij} - x_{ij}^e RT \ln f_{ij}^e) \right] \quad (4)$$

$$\frac{d(\Delta A)}{dt} = k'(\Delta A)^m \Rightarrow \Delta A = \frac{\alpha}{\sqrt{\alpha + kt}} \quad (5)$$

@ t = 0     ΔA = ΔA<sub>initial</sub> = ΔA<sub>max</sub>

$$\Delta A = n_T \sum_{i=1}^{N_c} \sum_{j=1}^{N_p} \left[ (x_{ij}(p) - x_{ij}^e) \mu_{ij}^\circ + (x_{ij}(p) - x_{ij}^e) RT \ln \frac{f_{ij}^{x_{ij}}}{(f_{ij}^e)^{x_{ij}}} \right] \quad (6)$$

$$\Delta A = n_T \sum_{i=1}^{N_c} \sum_{j=1}^{N_p} \left[ (x_{ij}(p) - x_{ij}^e) \mu_{ij}^\circ + RT \sum_{i=1}^{N_c} \sum_{j=1}^{N_p} \ln \frac{f_{ij}^{x_{ij}}}{(f_{ij}^e)^{x_{ij}}} \right] \quad (7)$$

$$\Delta A = n_T RT \sum_{i=1}^{N_c} \sum_{j=1}^{N_p} \ln \frac{f_{ij}^{x_{ij}}}{(f_{ij}^e)^{x_{ij}}} \quad (8)$$

$$\Delta A = n_T RT \sum_{i=1}^{N_c} \sum_{j=1}^{N_p} \ln \frac{f_{ij}^{x_{ij}}}{(f_{ij}^e)^{x_{ij}}} \quad (9)$$

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$\alpha \ m \ k$

$T(K)$	$k(J^{1/m}/s)$	$m$	$\alpha(J^{1/m}/s)$	$r$
	/	/	/	/
	/	/	/	/
	/	/	/	/
	/	/	/	/
	/	/	/	/

$\alpha \ m \ k$

$k(J^{1/m}/s)$	$m$	$k(J^{1/m}/s)$
/	/	/

( )

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$$\Delta A = (\dots \times t)^r$$

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K

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$\alpha \ m \ k$

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$\alpha \ m \ k$

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$\Delta A$

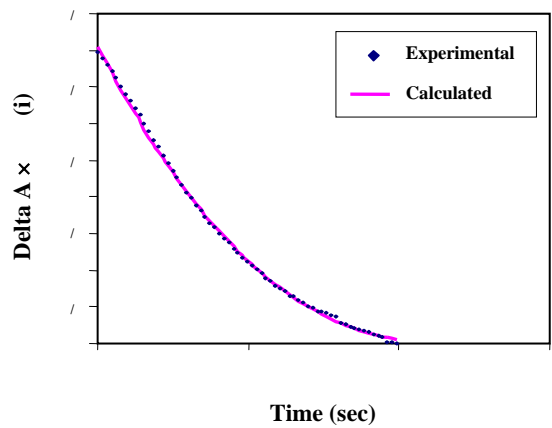
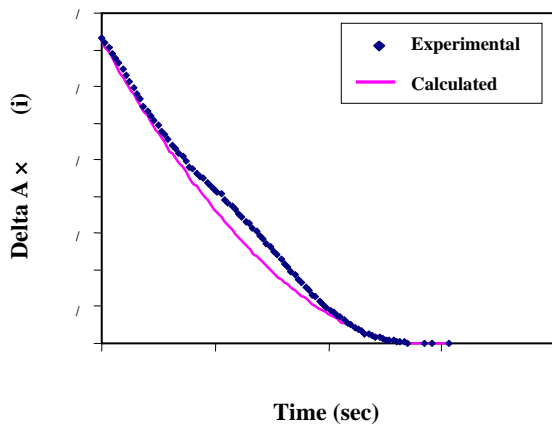
$\alpha \ m \ k$

$$d^r \Delta A / dt^r$$

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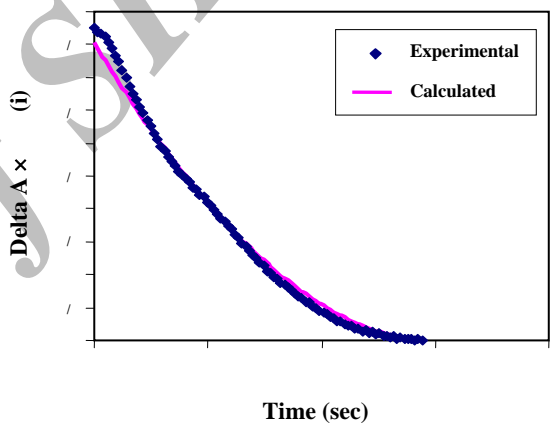
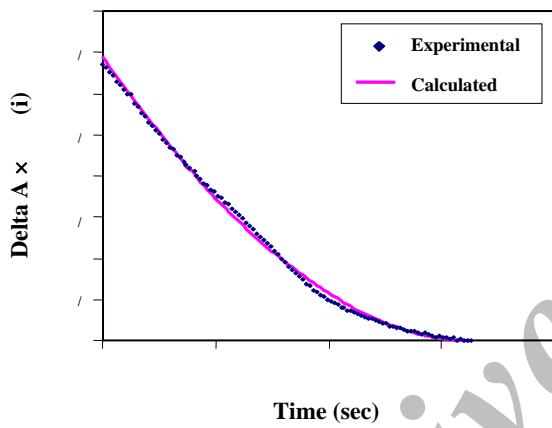
$\alpha \ m \ k$

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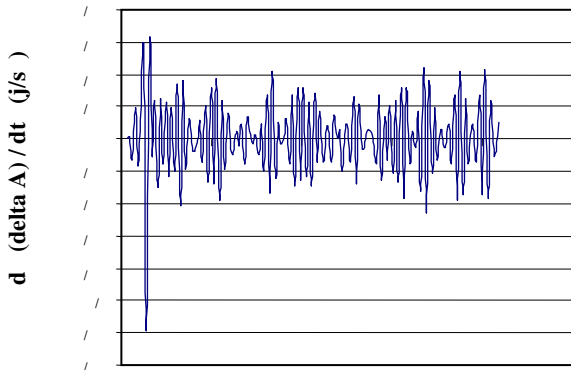
$N_C$   
 $N_P$   
 $n_T$   
 $x_{ij}$   
 $A$   
 $\mu_{ij}$   
 $R$

$j$   $i$   
 $j$   $i$

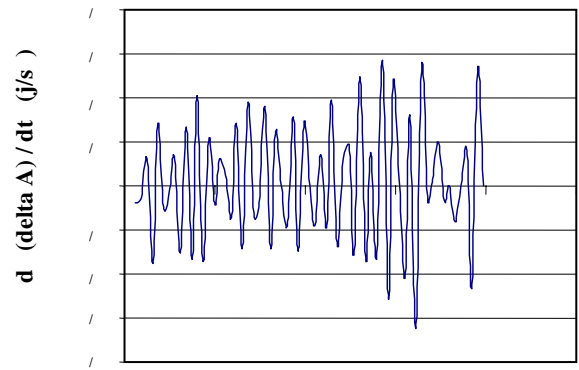
$$\Delta A = (\dots) \Rightarrow \quad ( )$$

$$\frac{d(\Delta A)}{dt} = \dots \Rightarrow$$

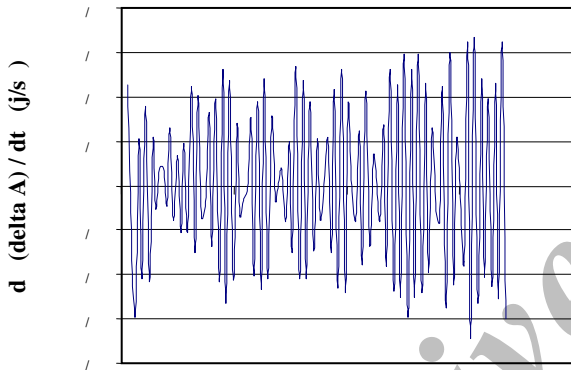
$$\frac{d^r(\Delta A)}{dt^r} = \dots \Rightarrow$$



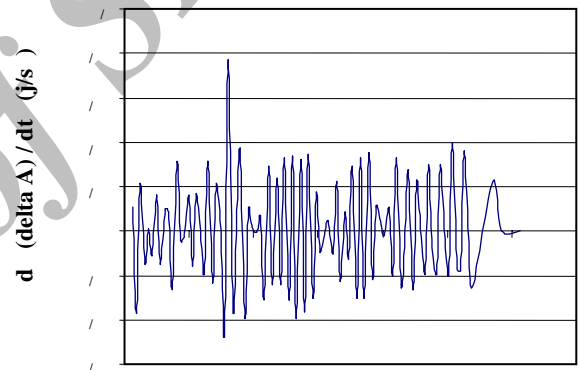
Time (s)



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$\Delta A$

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