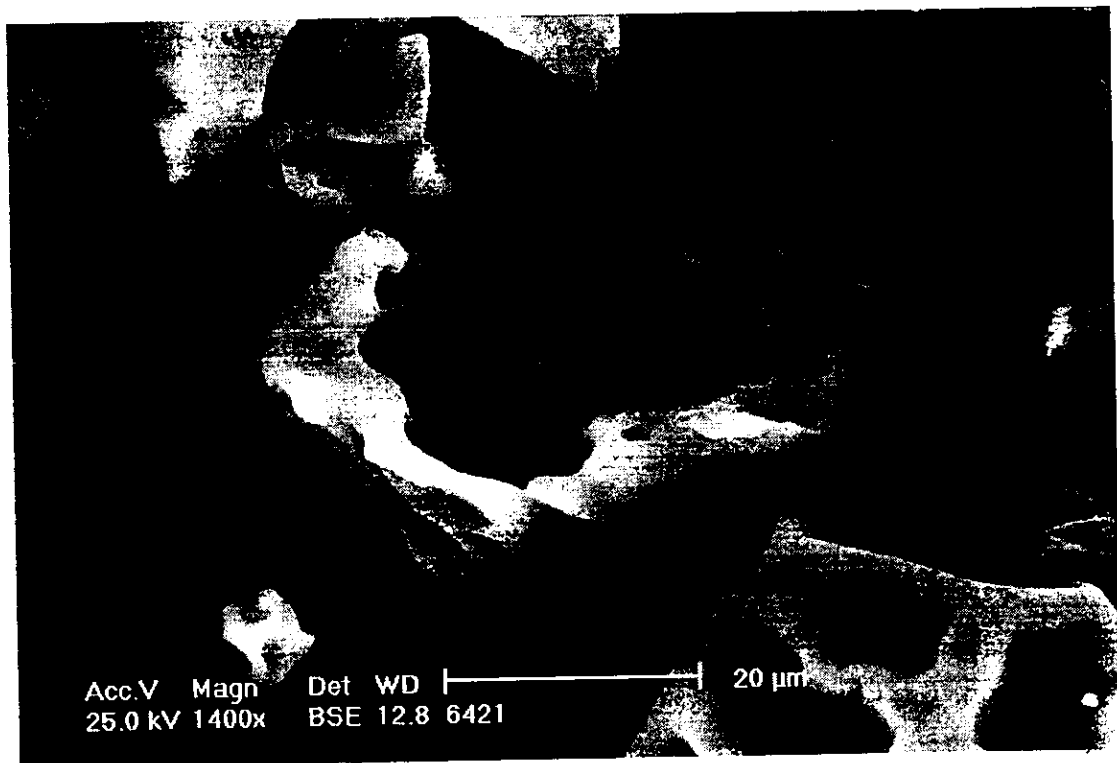


GA50-MD50 pH 4, relación 2:1



GM50-MD50 pH 4, relación 2:1



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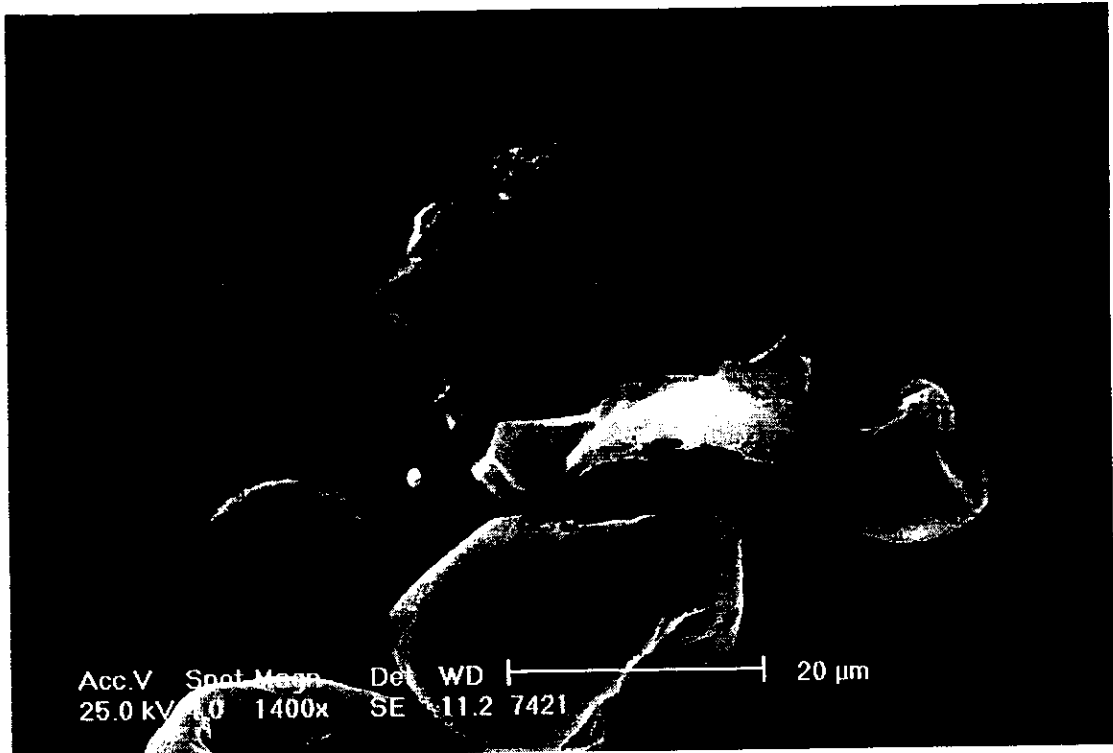


**UNAM – Dirección General de Bibliotecas**  
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**Restricciones de uso**

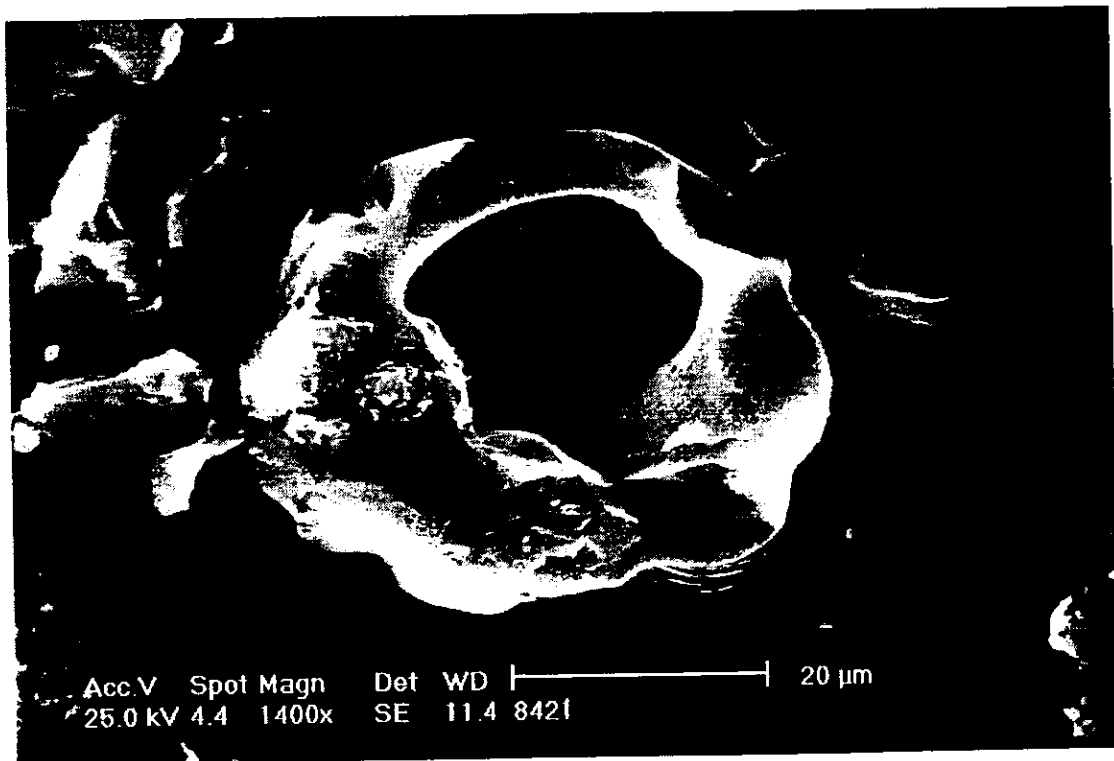
**DERECHOS RESERVADOS ©**  
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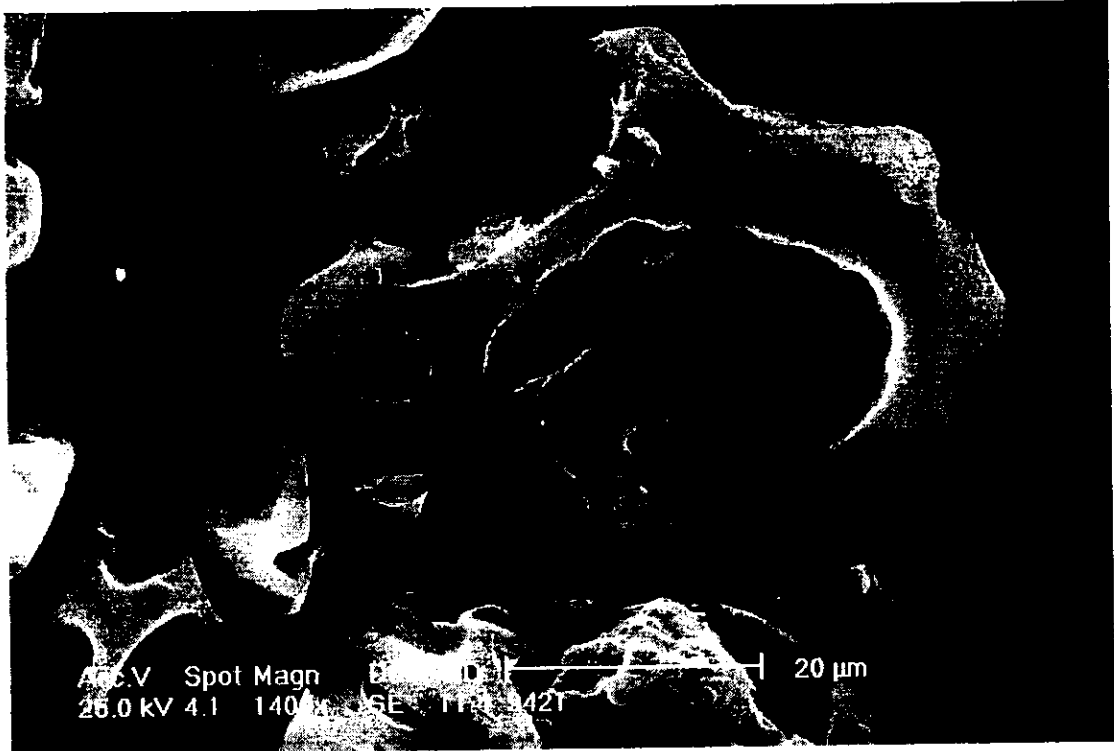
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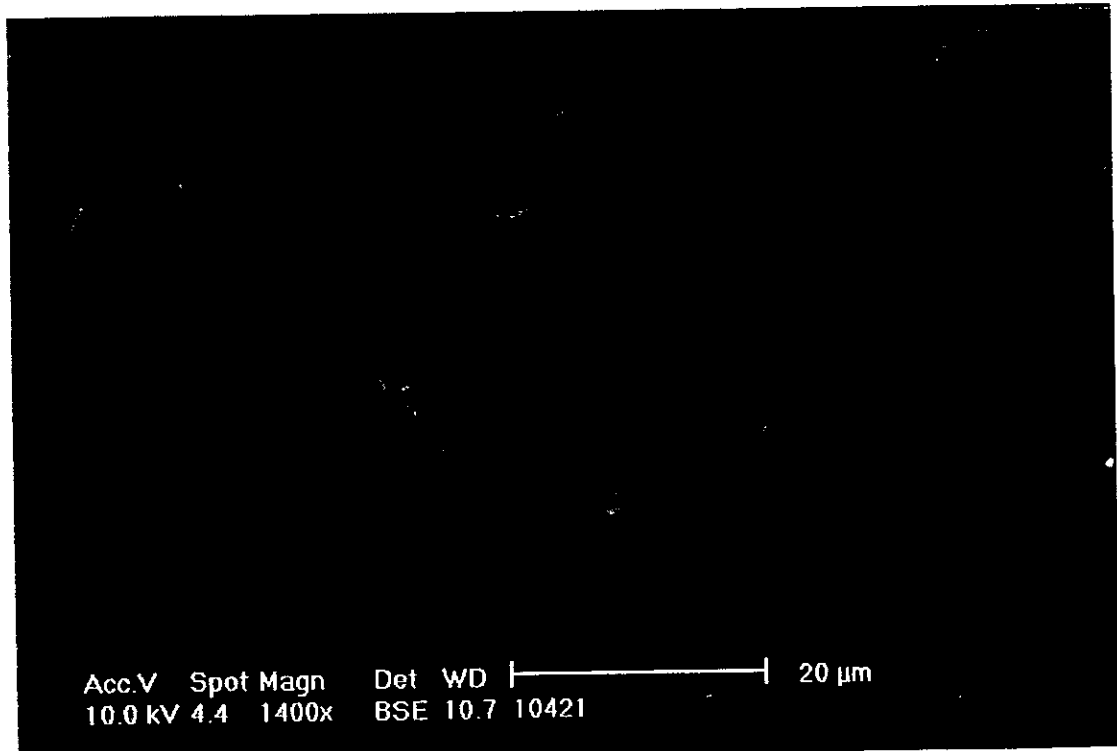
GA33-GM33-MD33 pH 4, relación 2:1



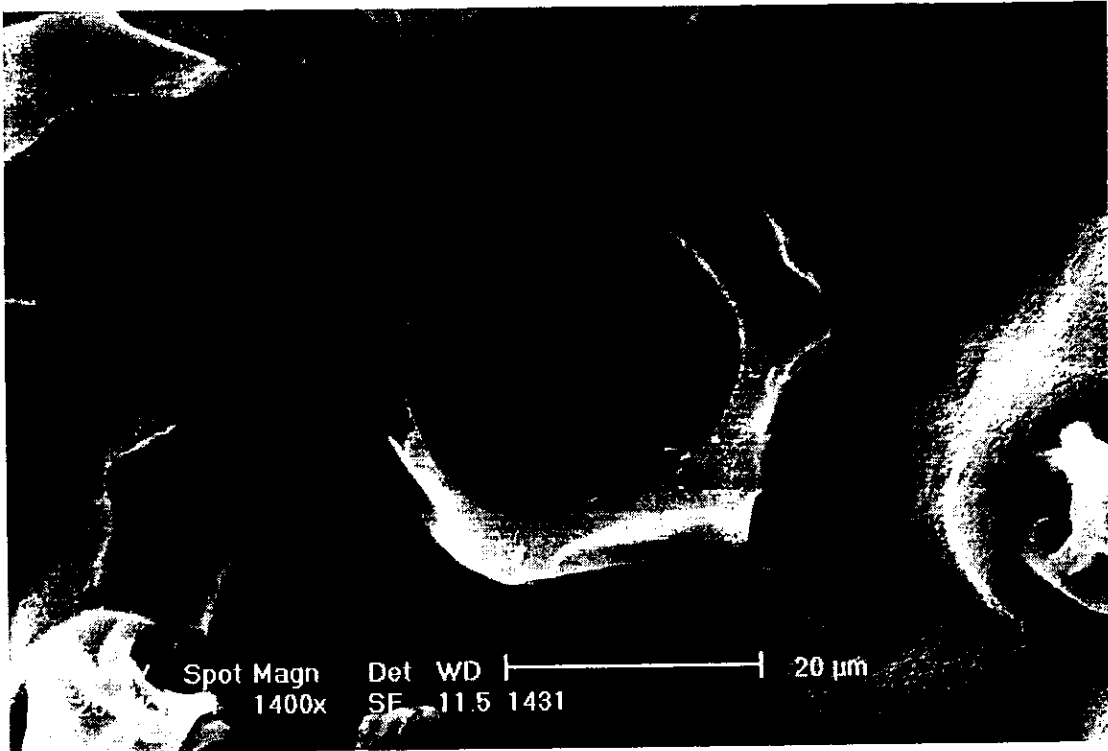
GA66-GM17-MD17 pH 4, relación 2:1



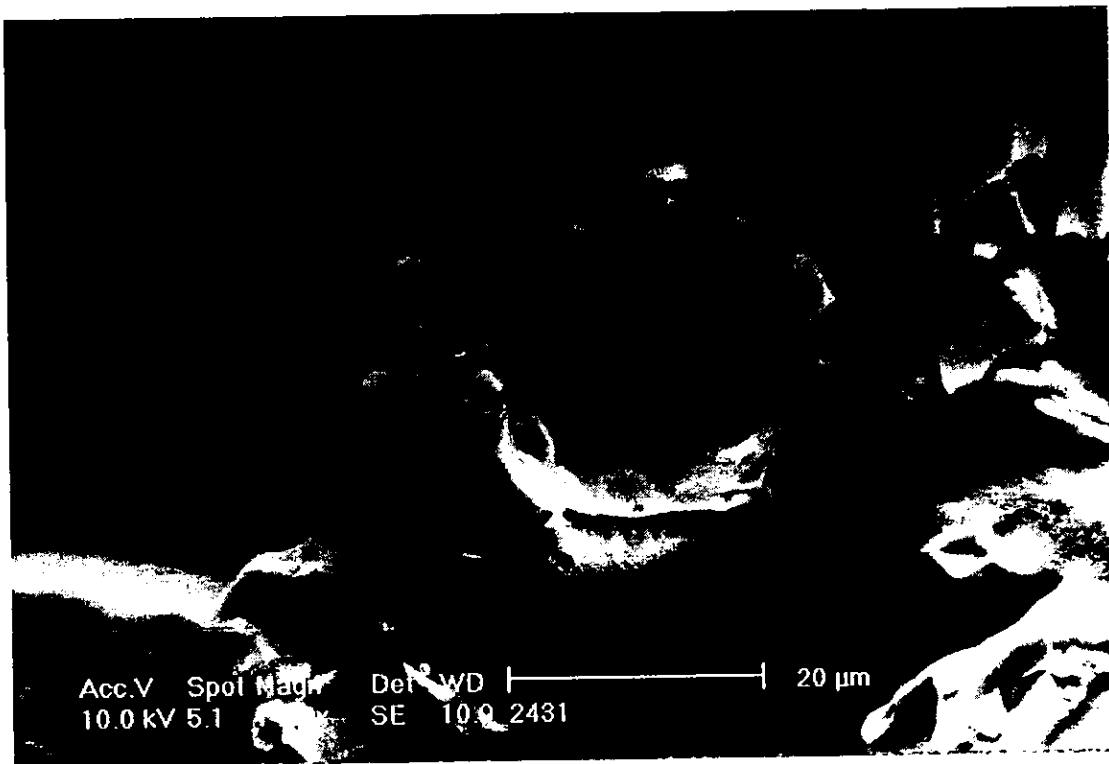
GA17-GM66-MD17 pH 4, relación 2:1



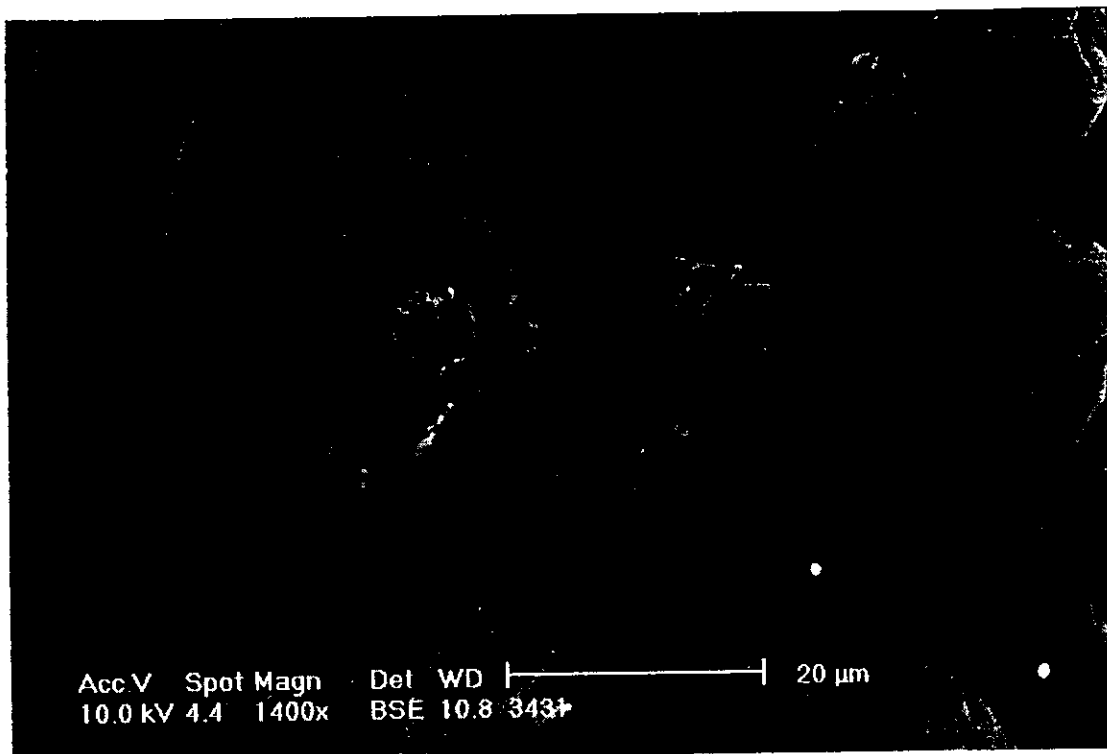
GA17-GM17-MD66 pH 4, relación 2:1



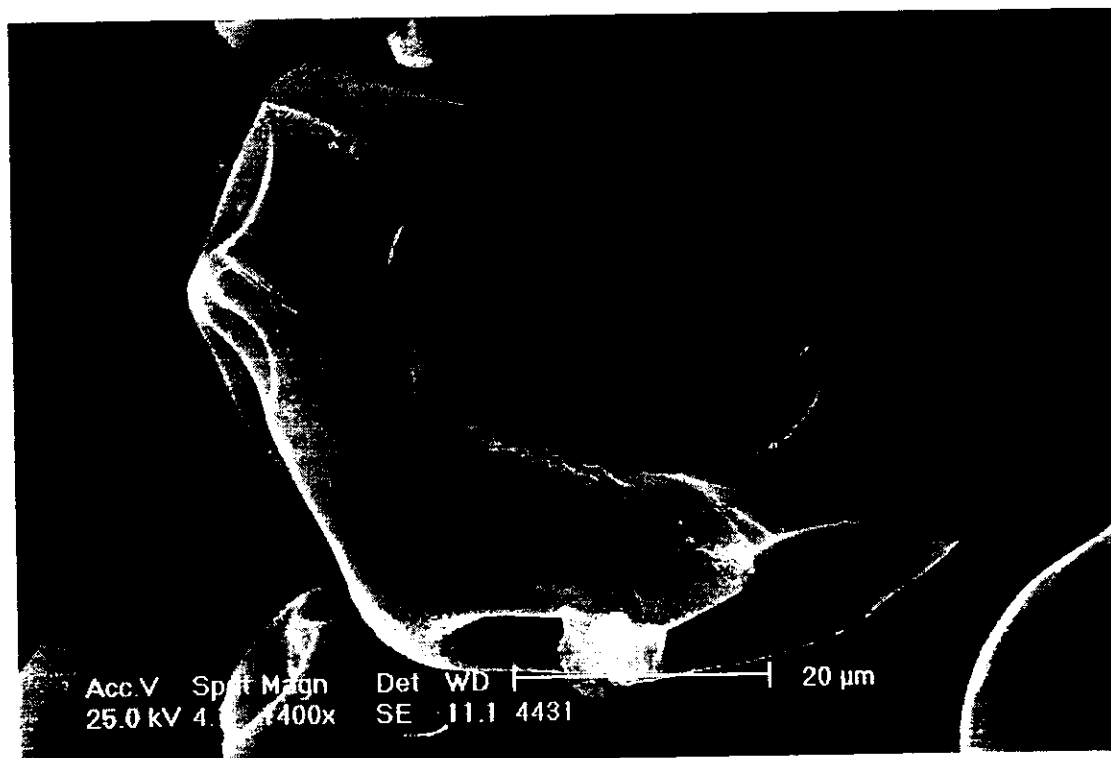
GA100 pH 4, relación 3:1



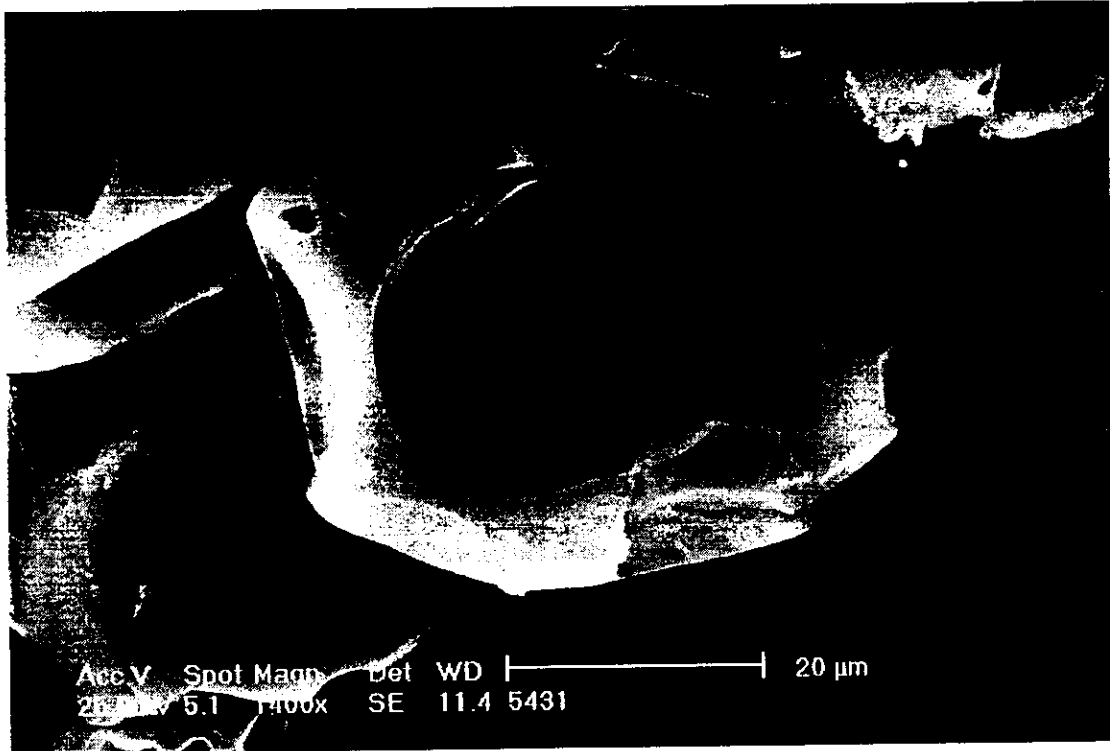
GM100 pH 4, relación 3:1



MD100 pH 4, relación 3:1



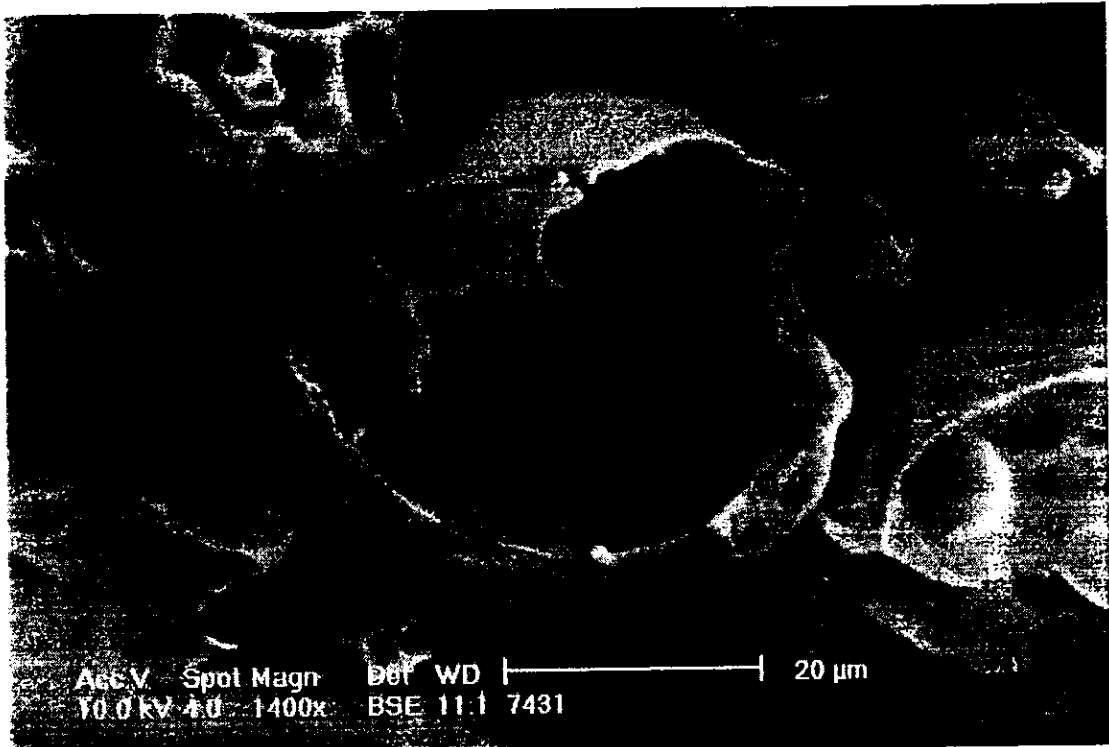
GA50-GM50 pH 4, relación 3:1



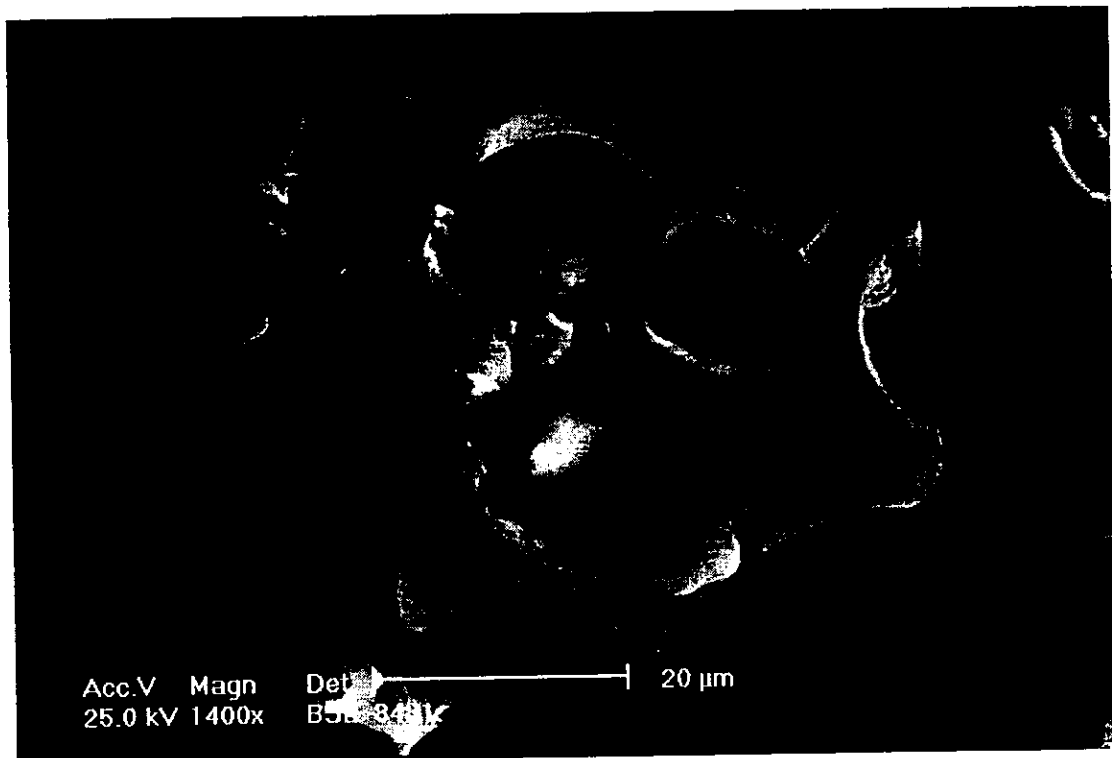
GA50-MD50 pH 4, relación 3:1



GM50-MD50 pH 4, relación 3:1

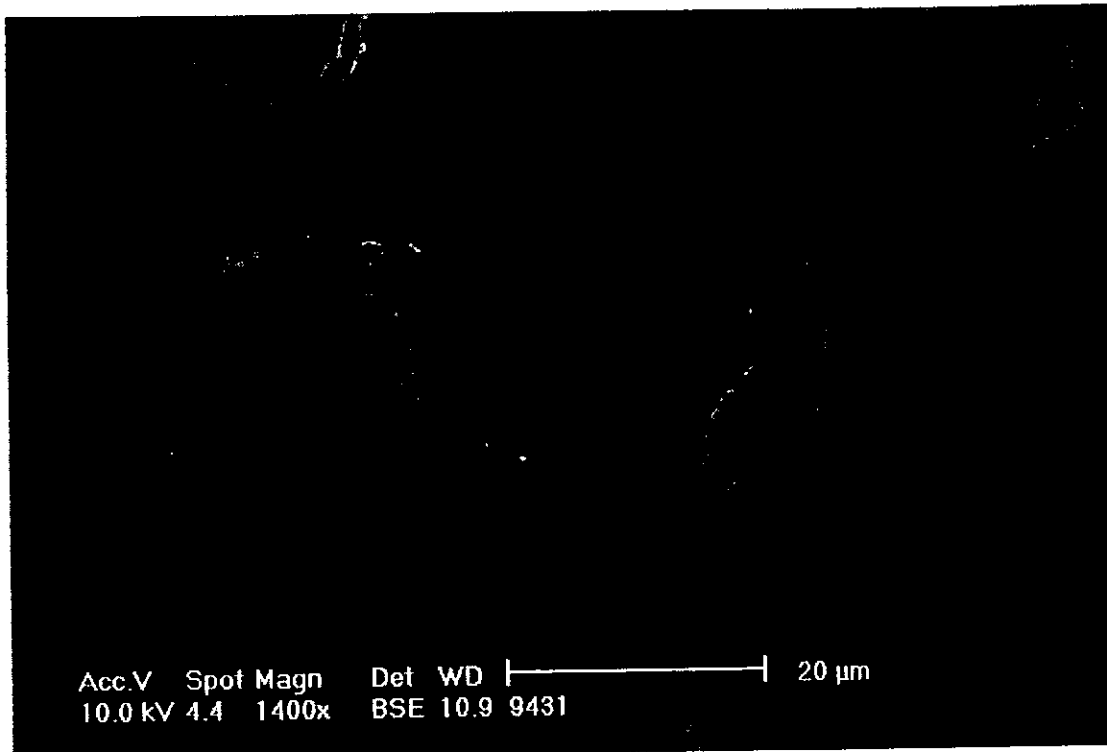


GA33-GM33-MD33 pH 4, relación 3:1



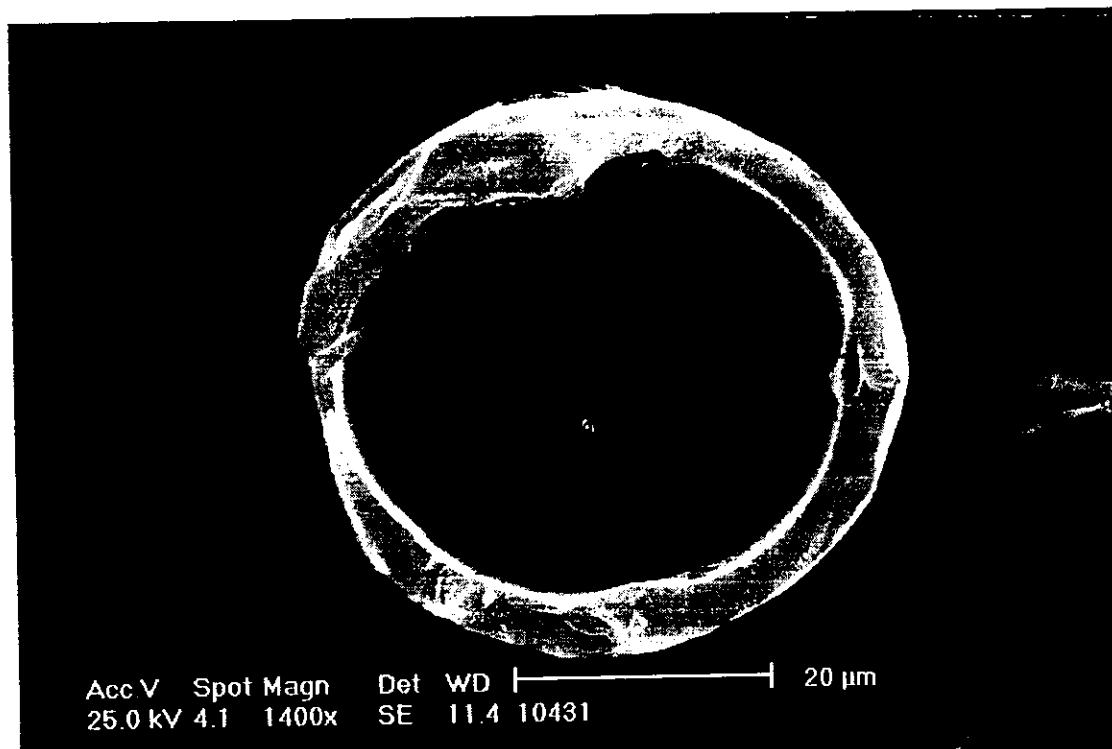
GA66-GM17-MD17 pH 4, relación 3:1





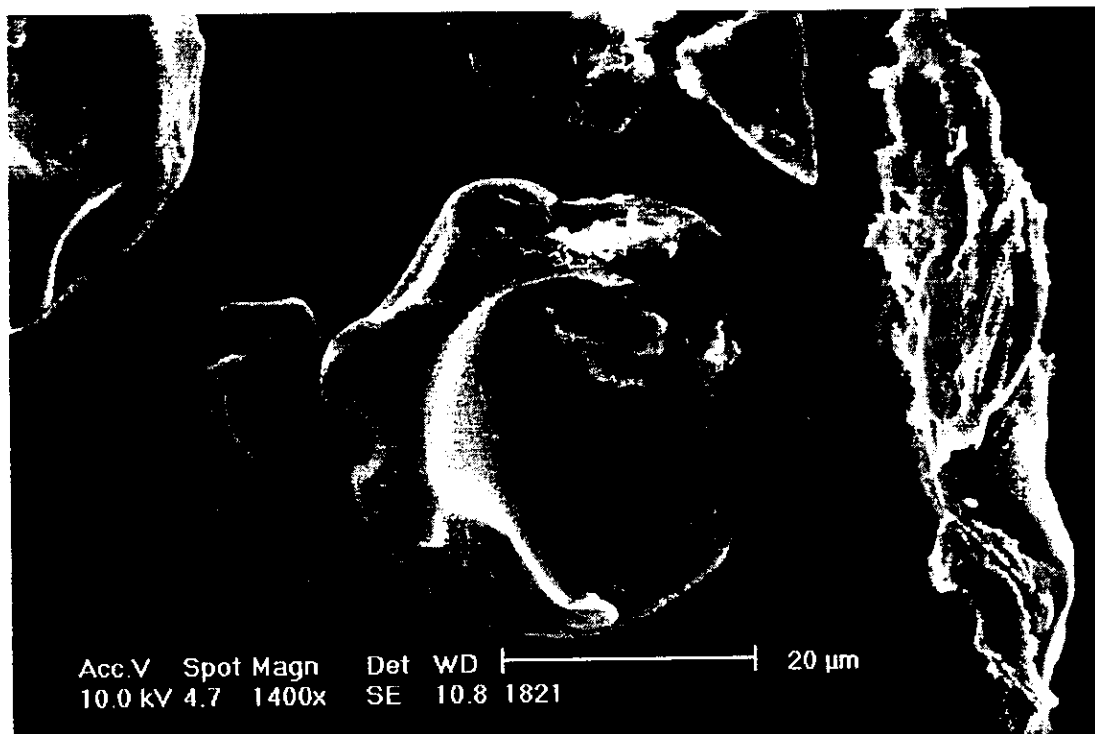
Acc.V Spot Magn Det WD |-----| 20 µm  
10.0 kV 4.4 1400x BSE 10.9 9431

GA17-GM66-MD17 pH 4, relación 3:1

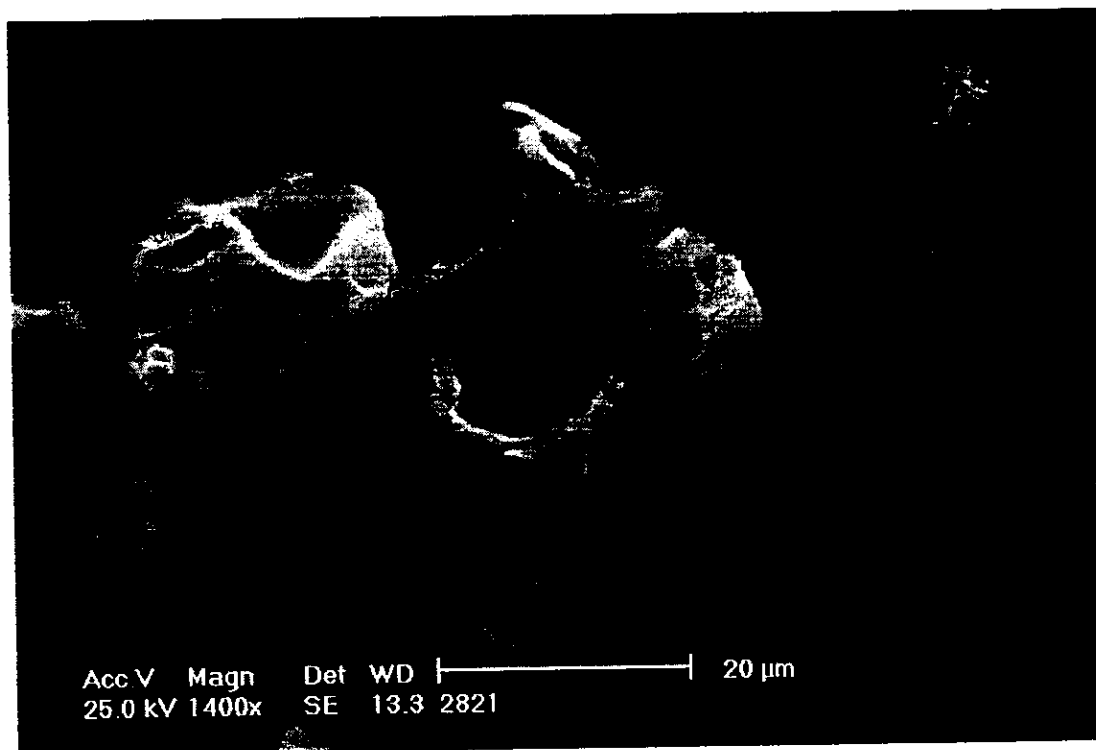


Acc.V Spot Magn Det WD |-----| 20 µm  
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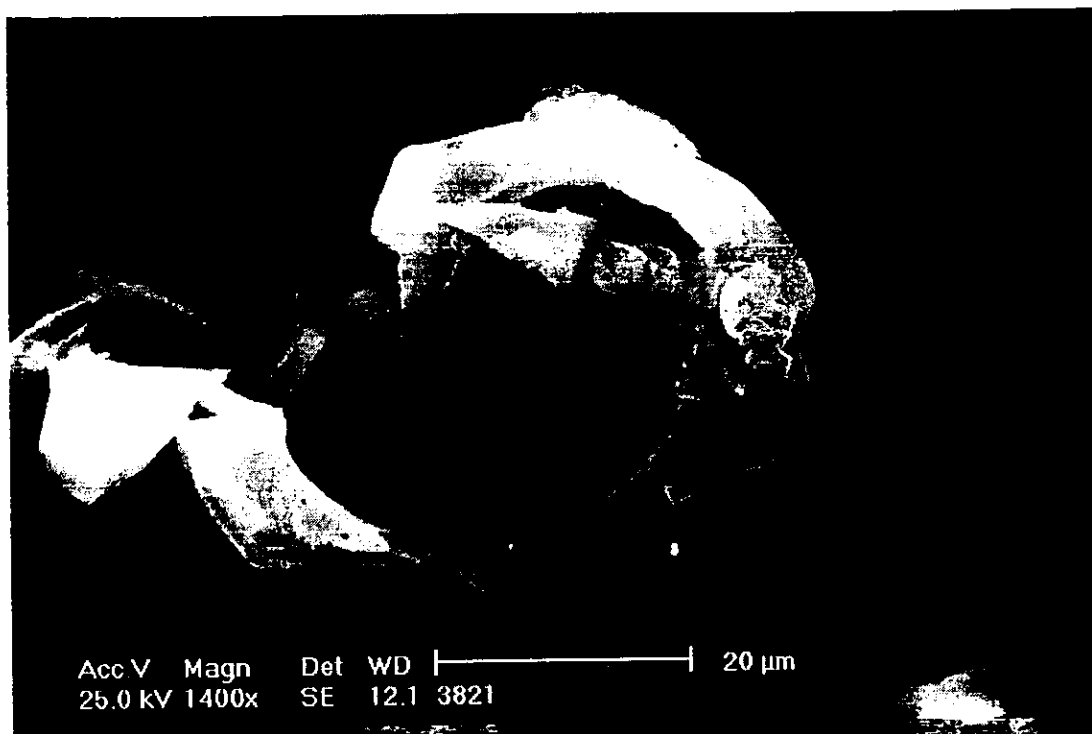
GA17-GM17-MD66 pH 4, relación 3:1



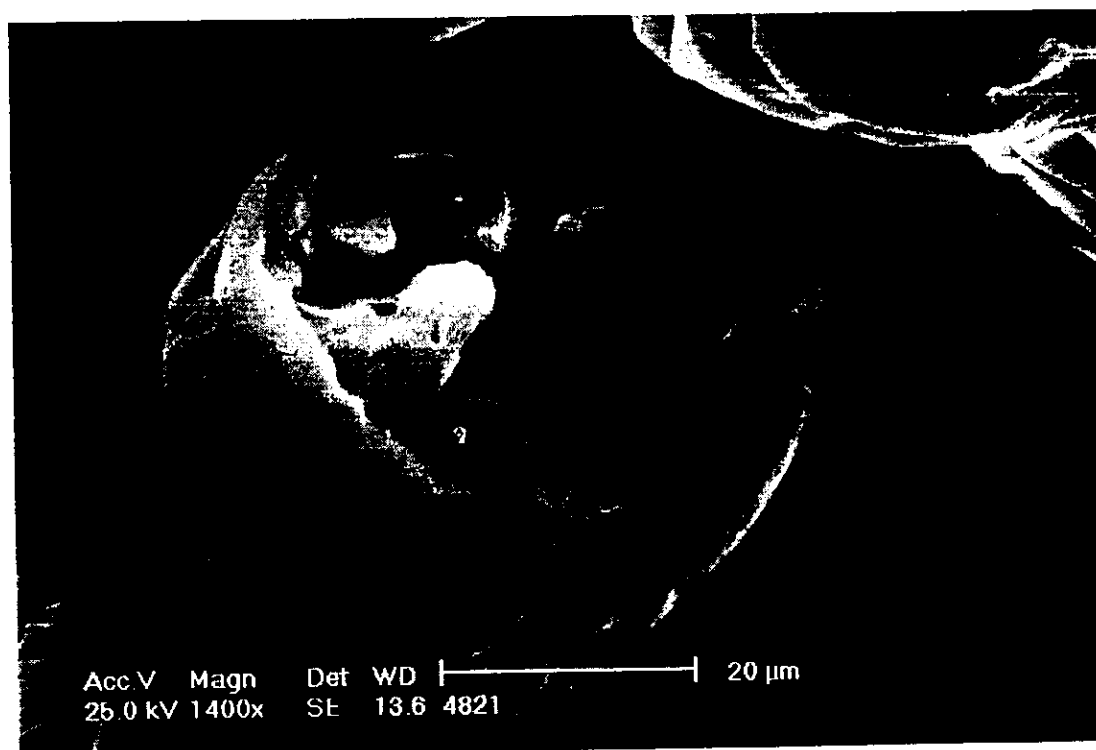
GA100 pH8, relación 2:1



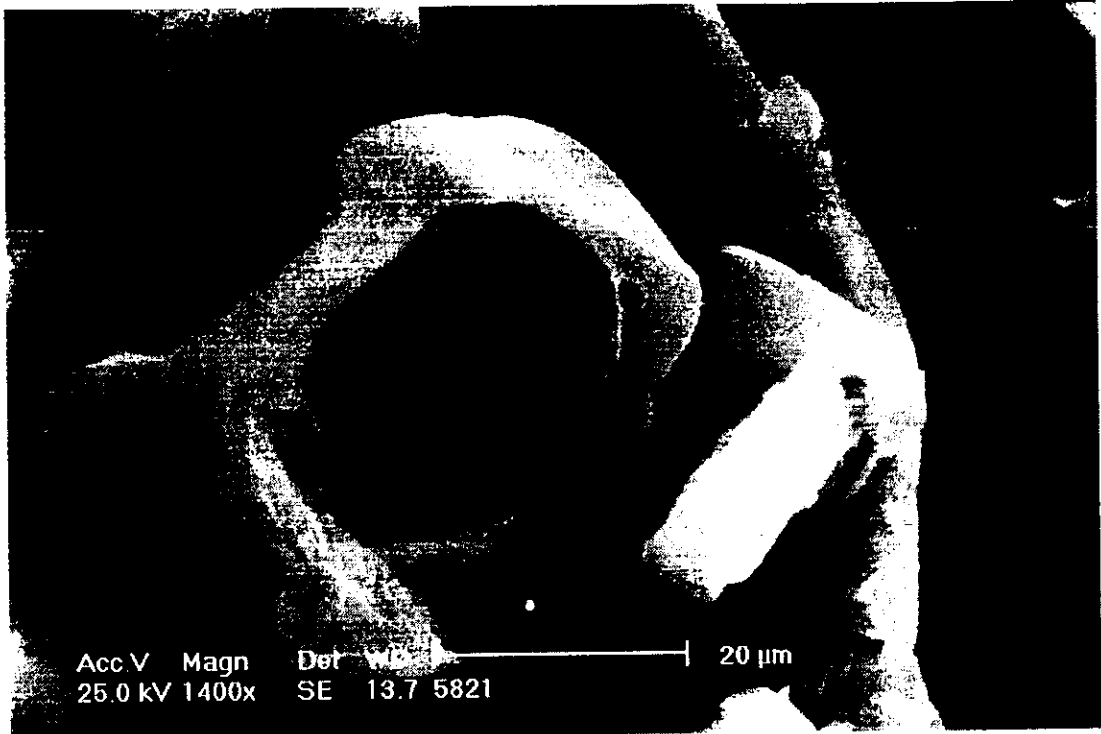
GM100 pH 8, relación 2:1



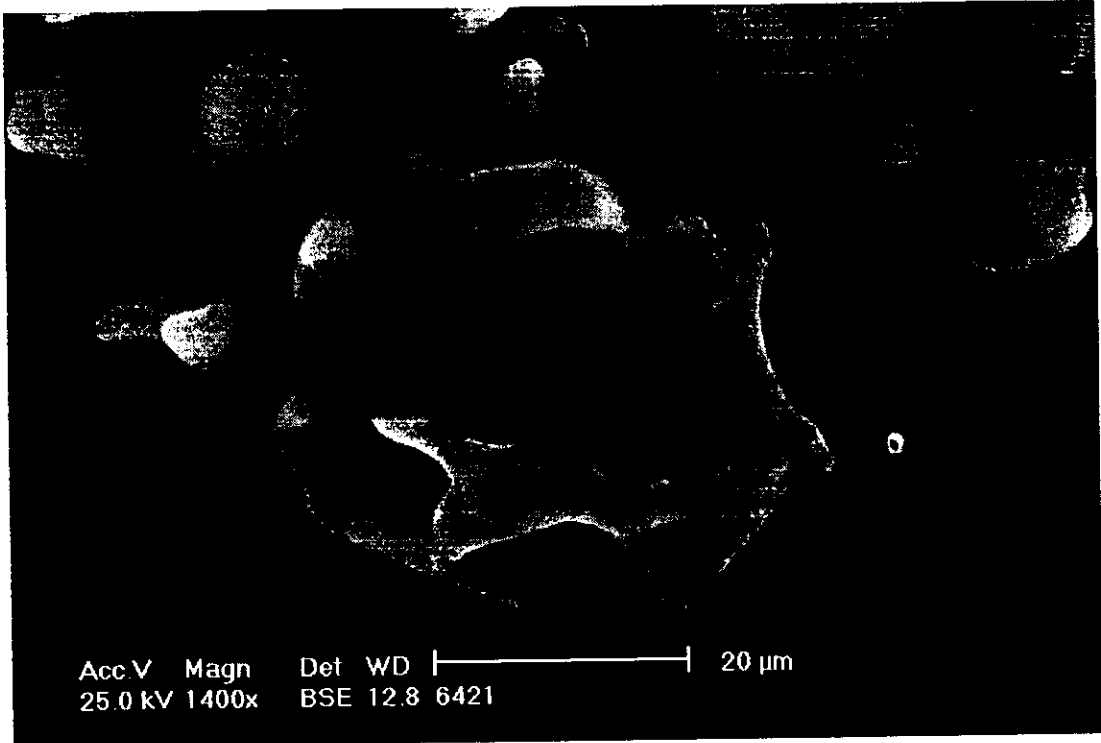
MD100 pH , relación 2:1



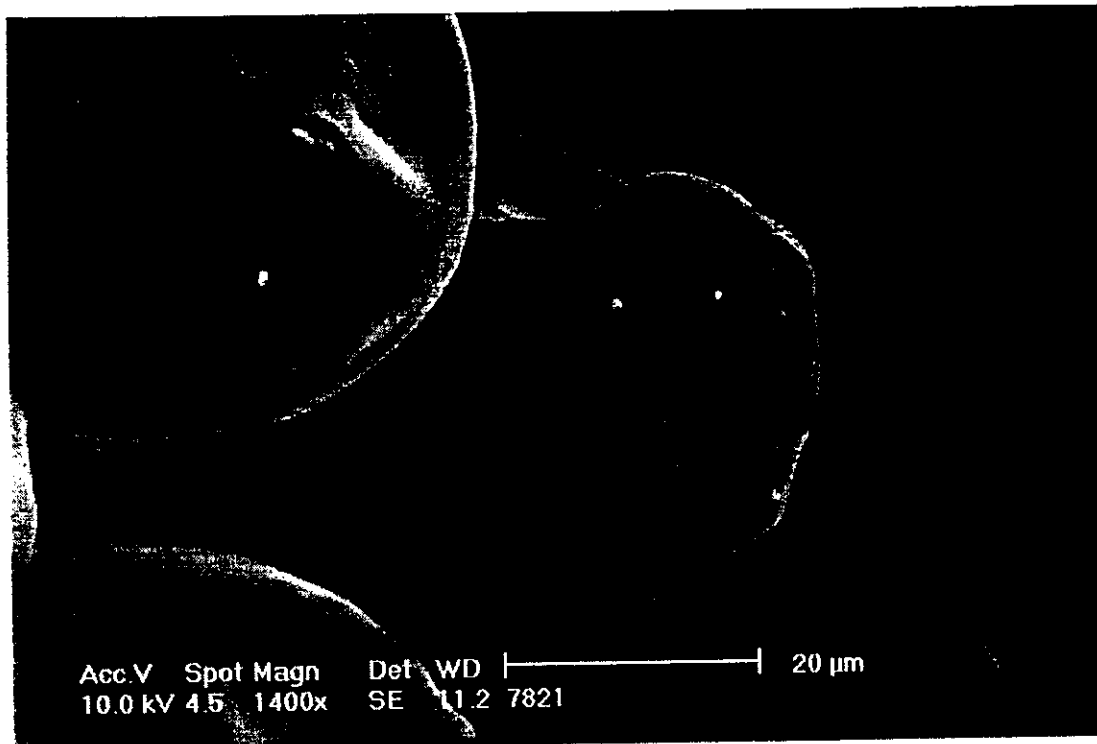
GA50-GM50 pH 8, relación 2:1



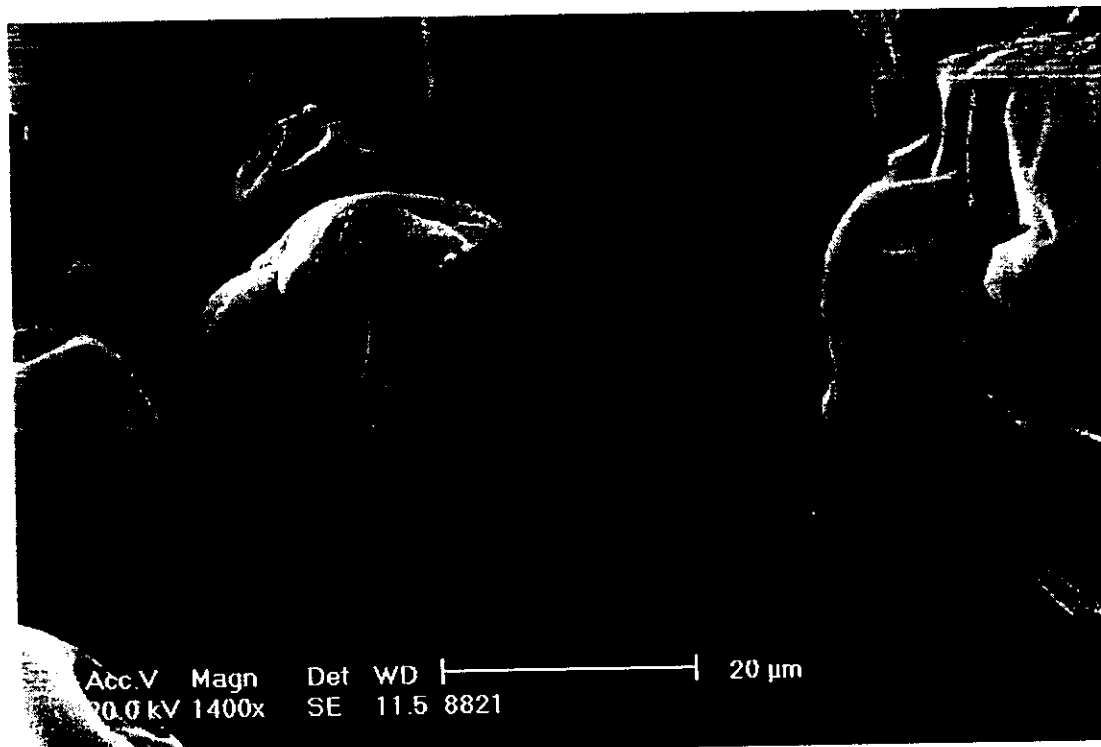
GA50-MD50 pH 8, relación 3:1



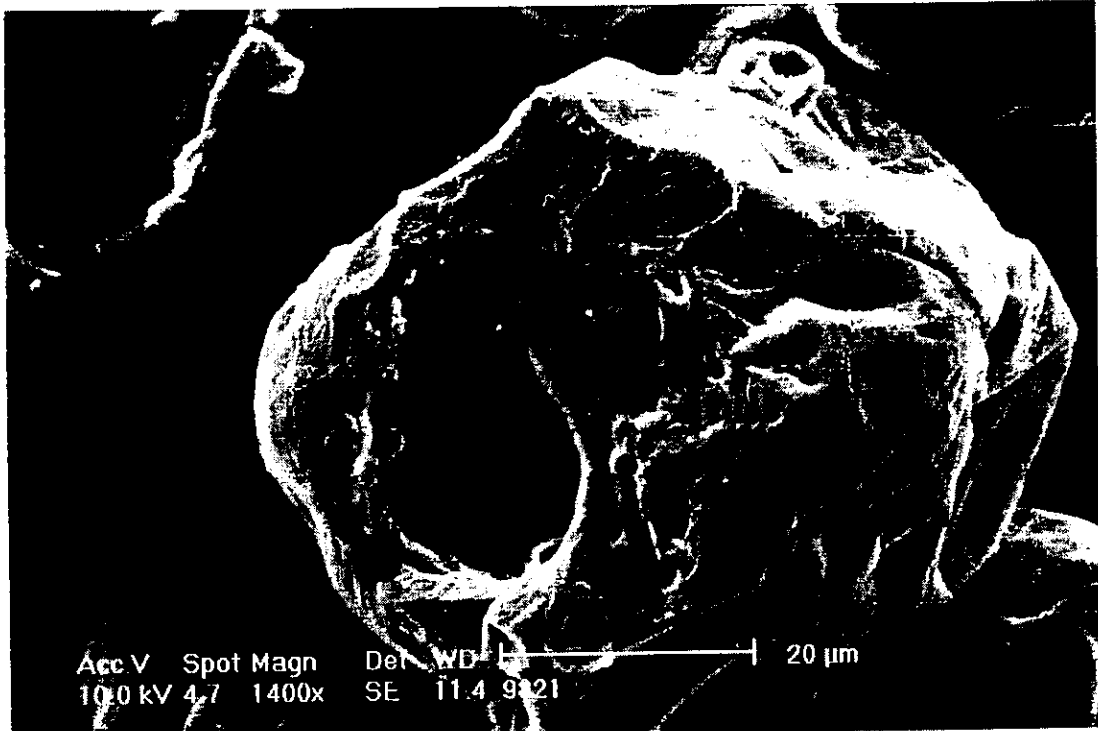
GM50-MD50 pH 8, relación 2:1



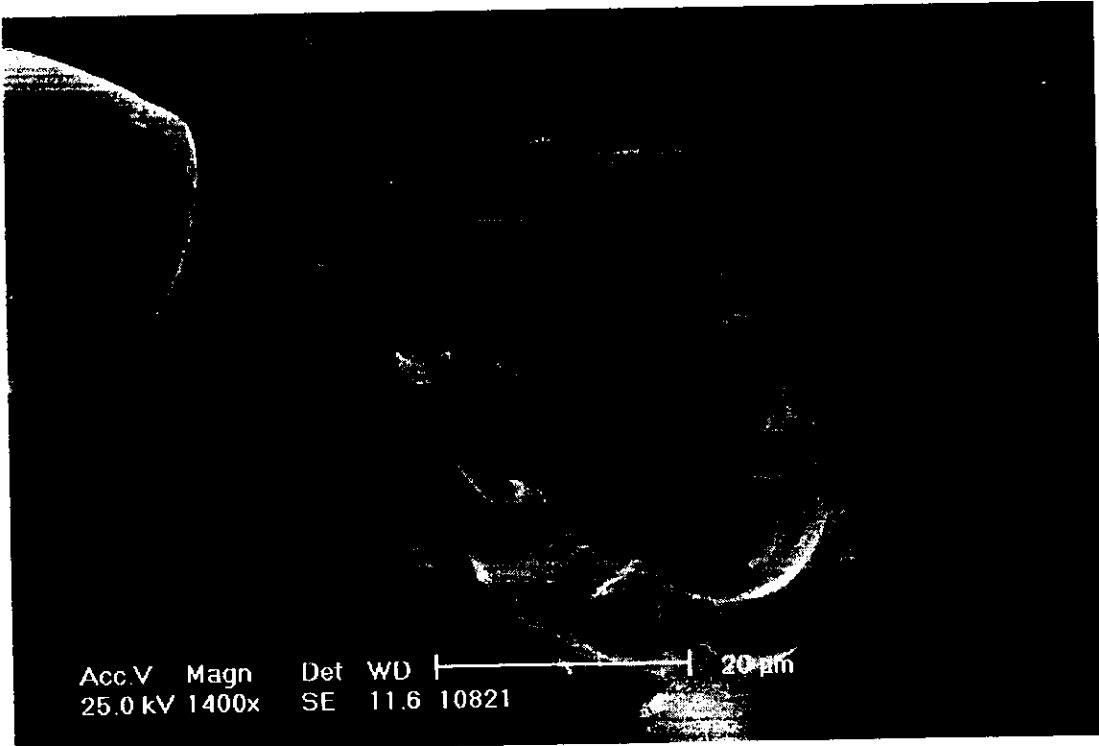
GA33-GM33-MD33 pH 8, relación 2:1



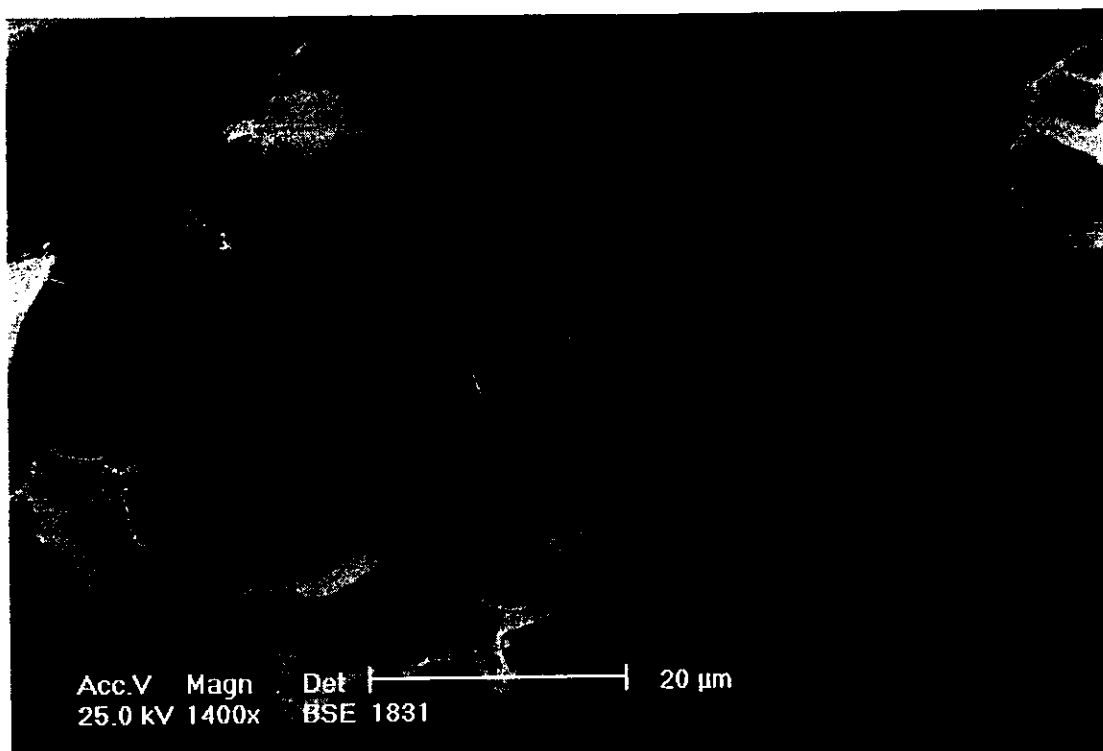
GA66-GM17-MD17 pH 8, relación 2:1



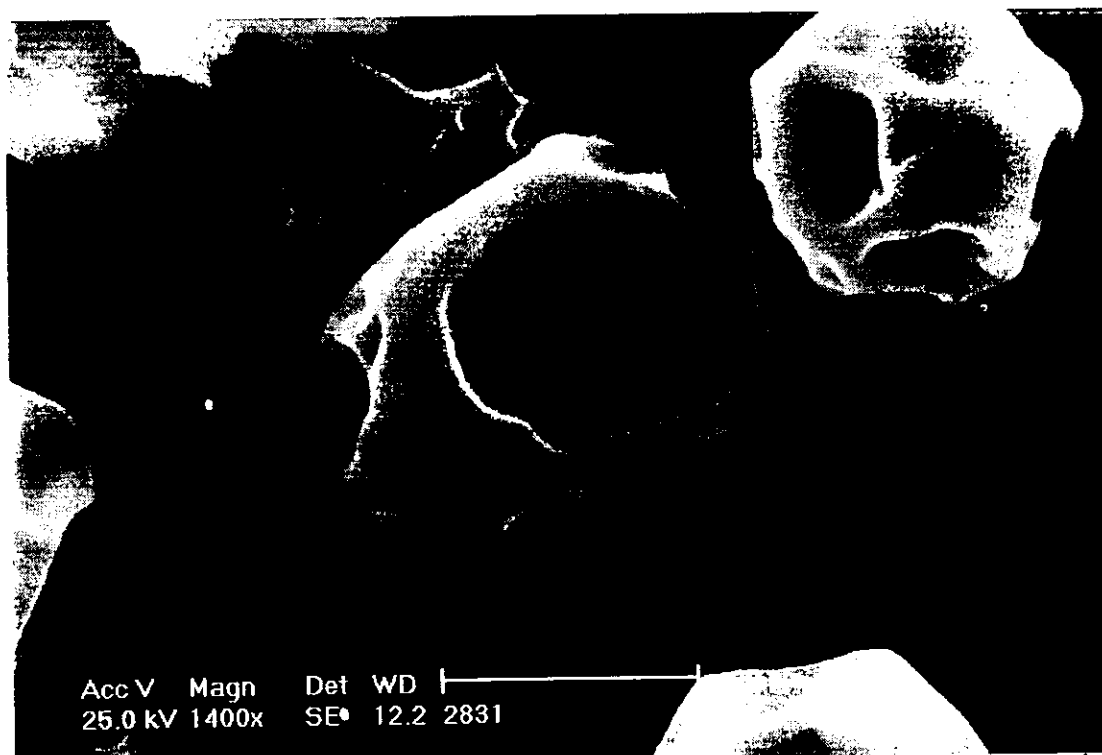
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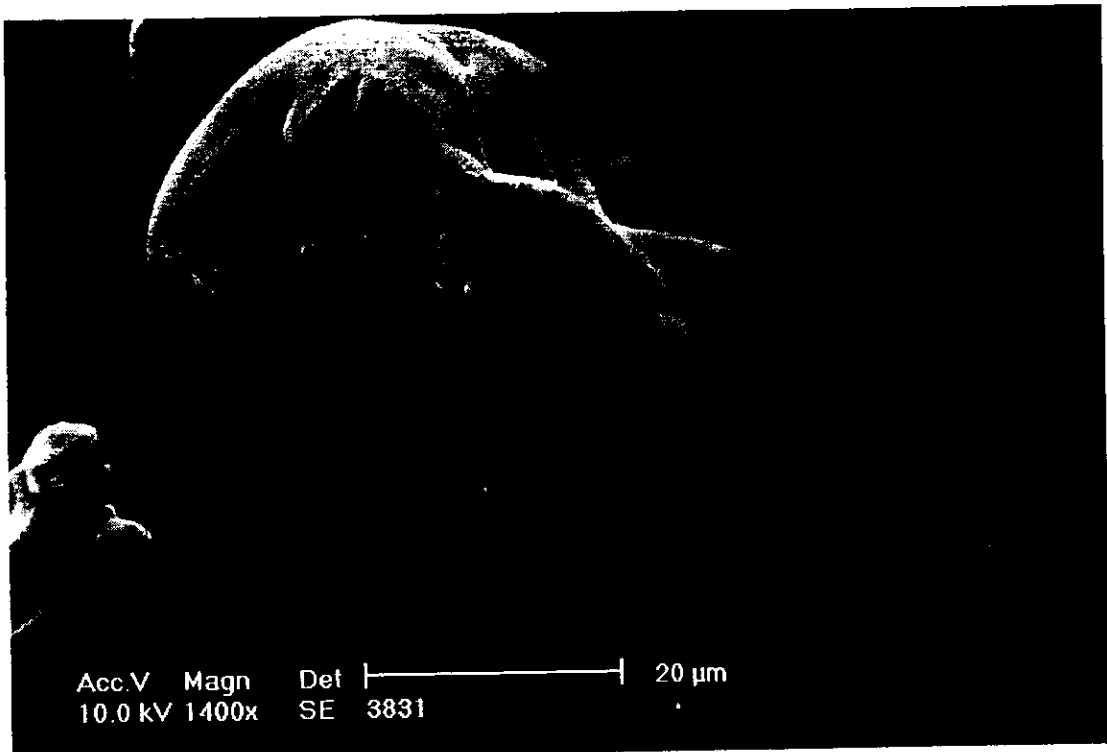
GA17-GM17-MD66 pH 8, relación 2:1



GA100 pH 8, relación 3:1



GM100 pH 8, relación 3:1

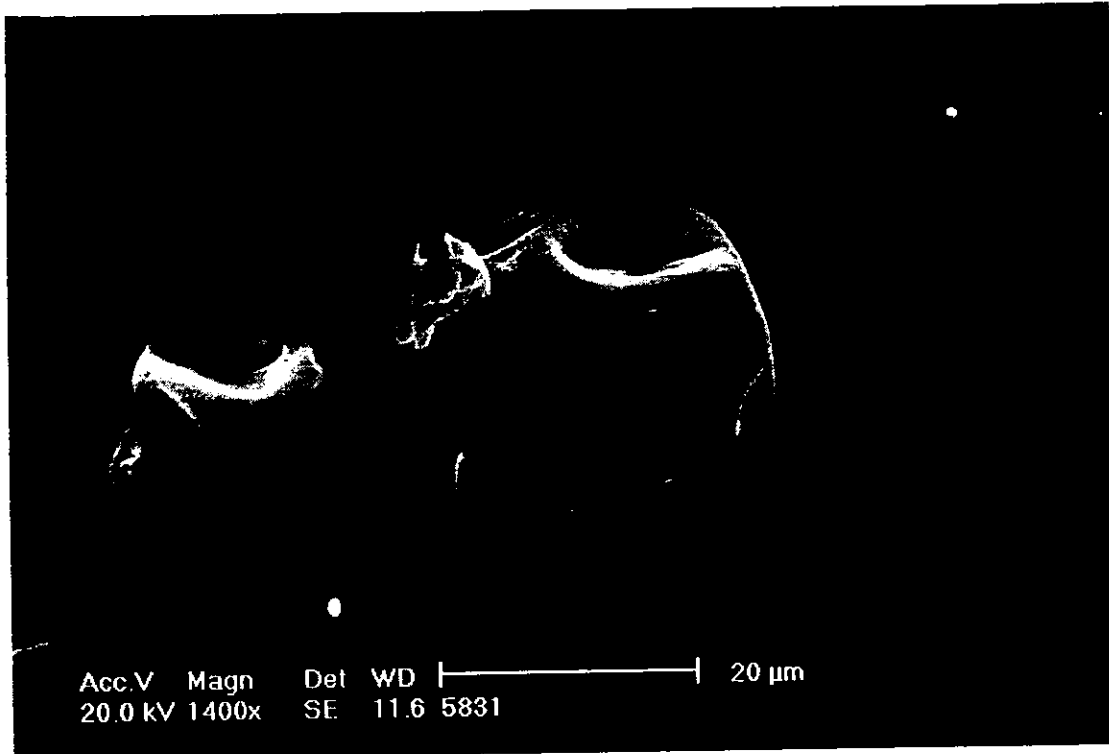


MD100 pH 8, relación 3:1

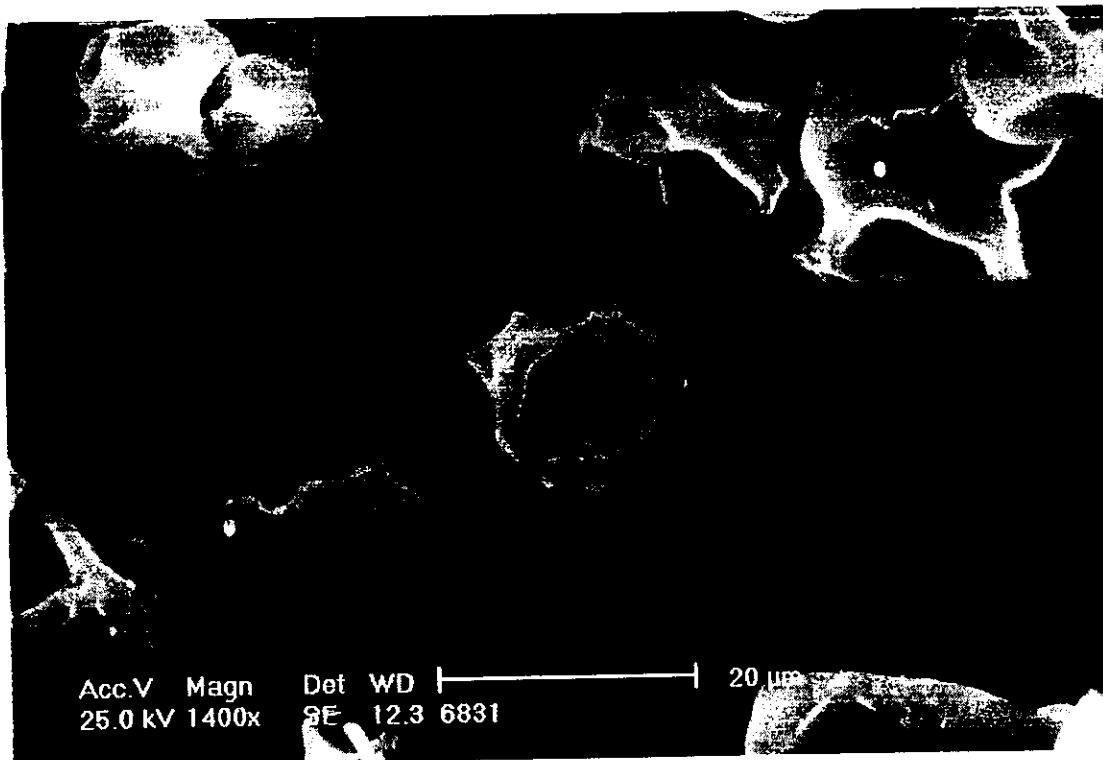


GA50-GM50 pH 8, relación 3:1

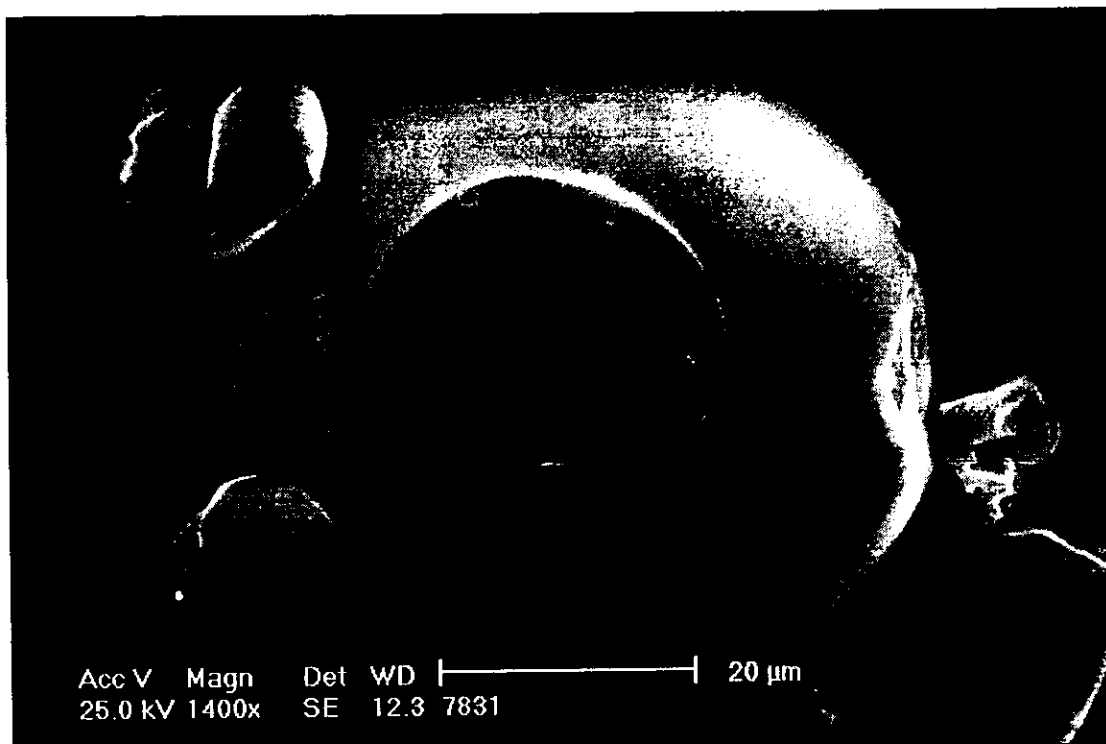




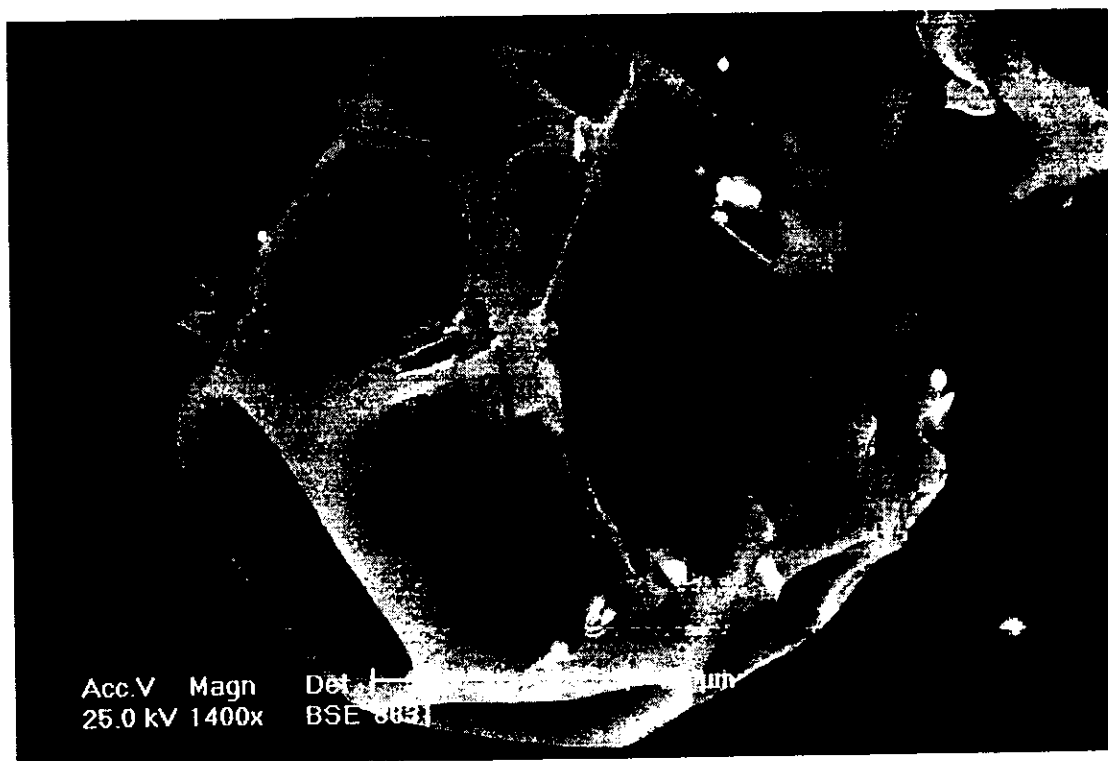
GA50-MD50 pH 8, relación 3:1



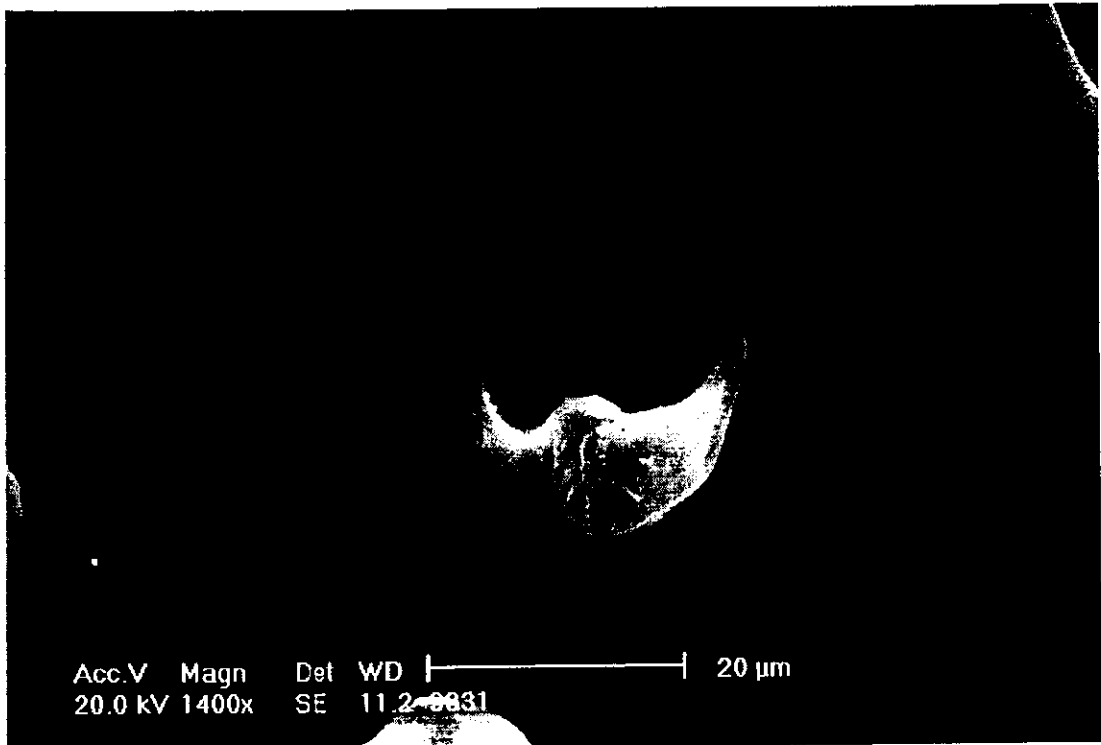
GM50-MD50 pH 8, relación 3:1



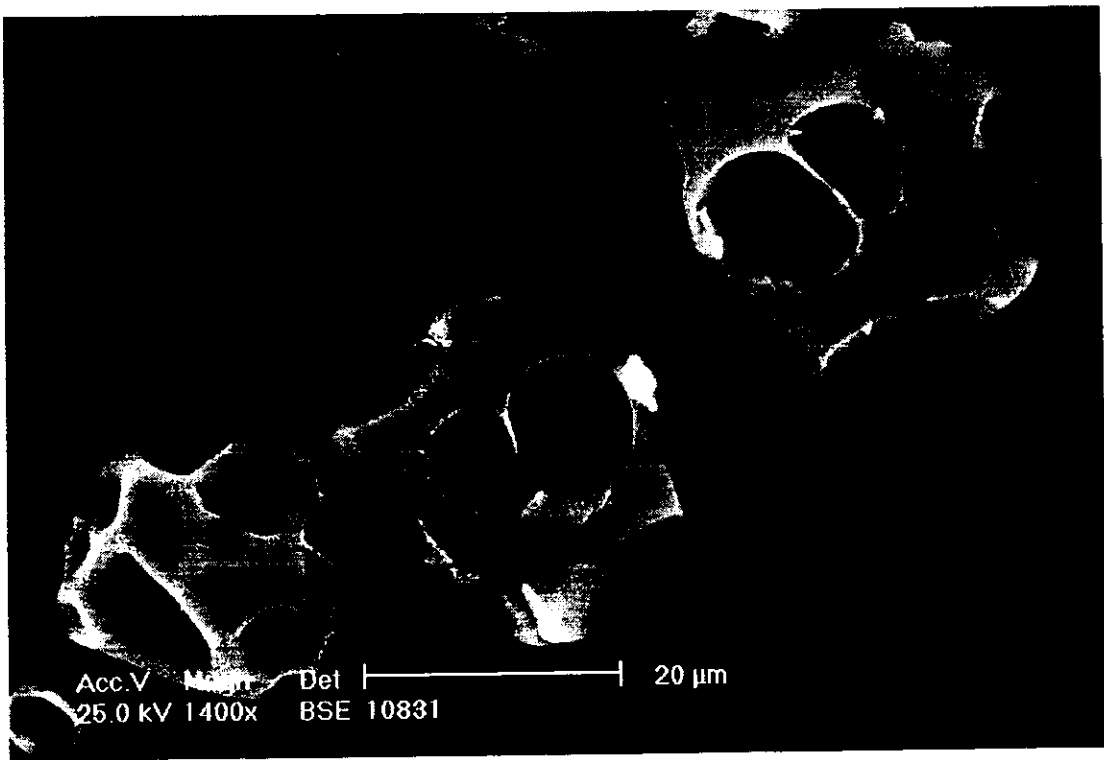
GA33-GM33-MD33 pH 8, relación 3:1



GA66-GM17-MD17 pH 8, relación 3:1

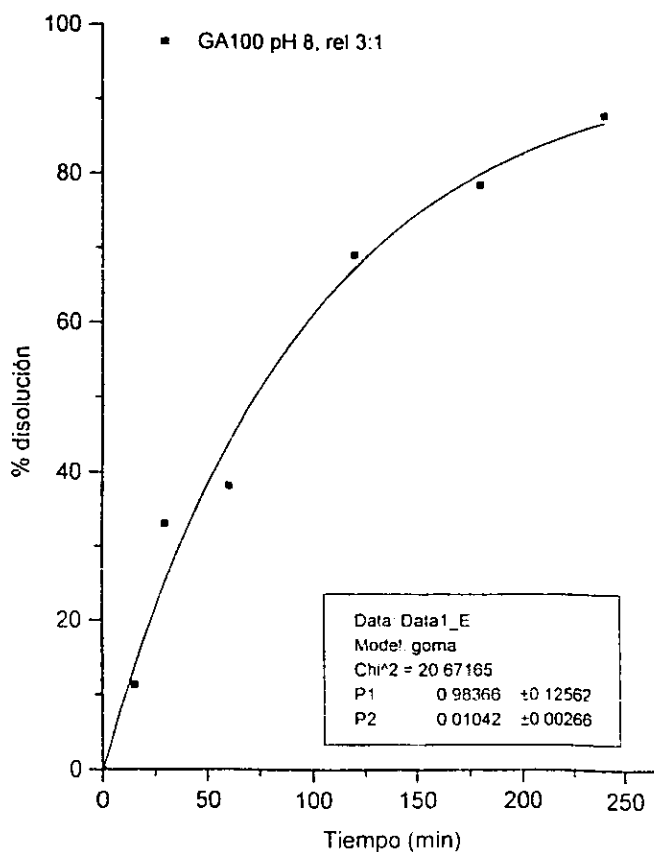
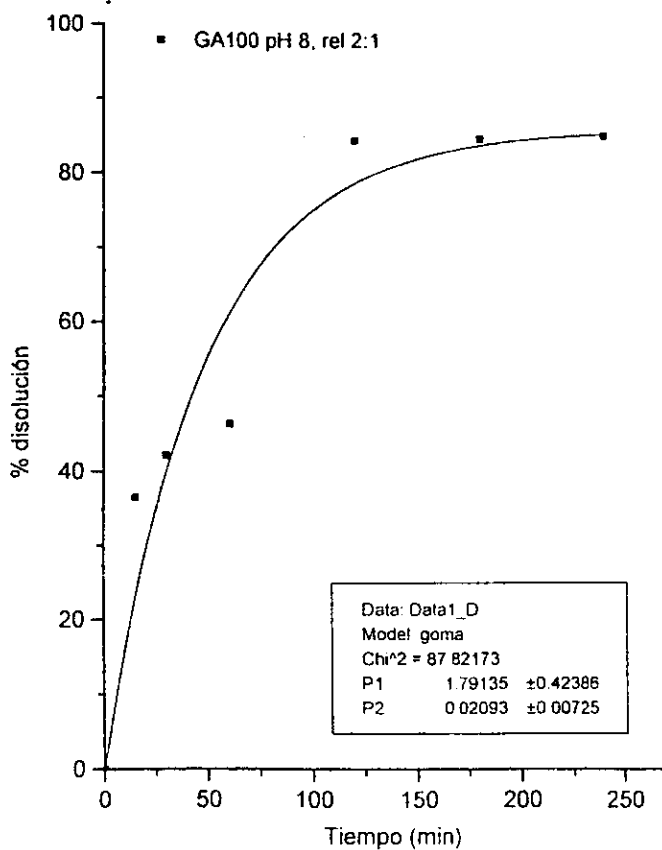
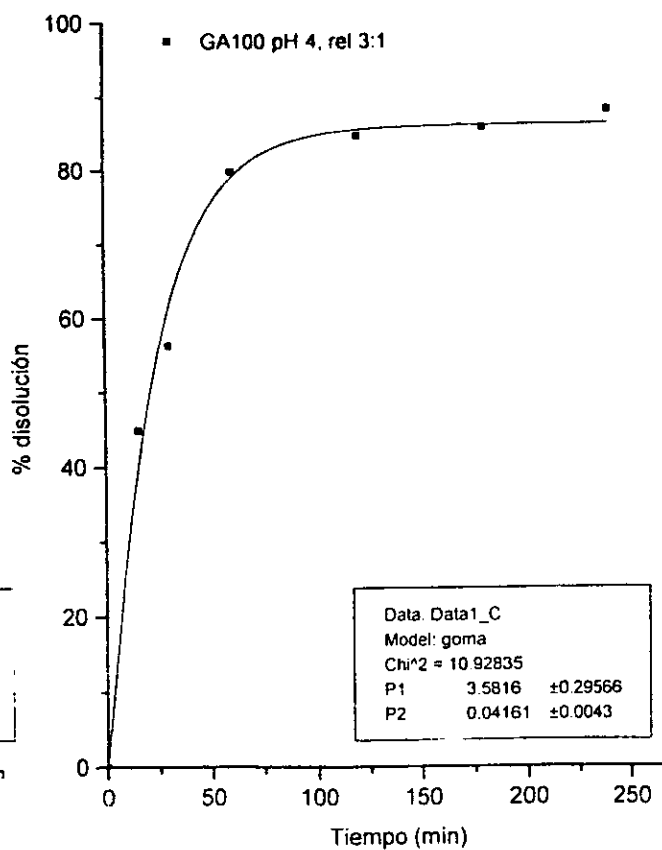
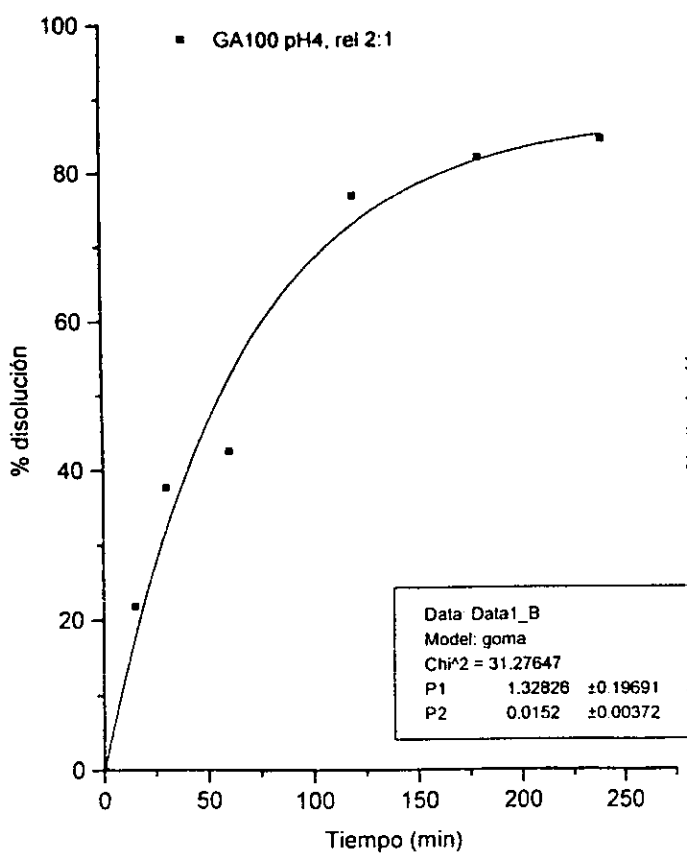


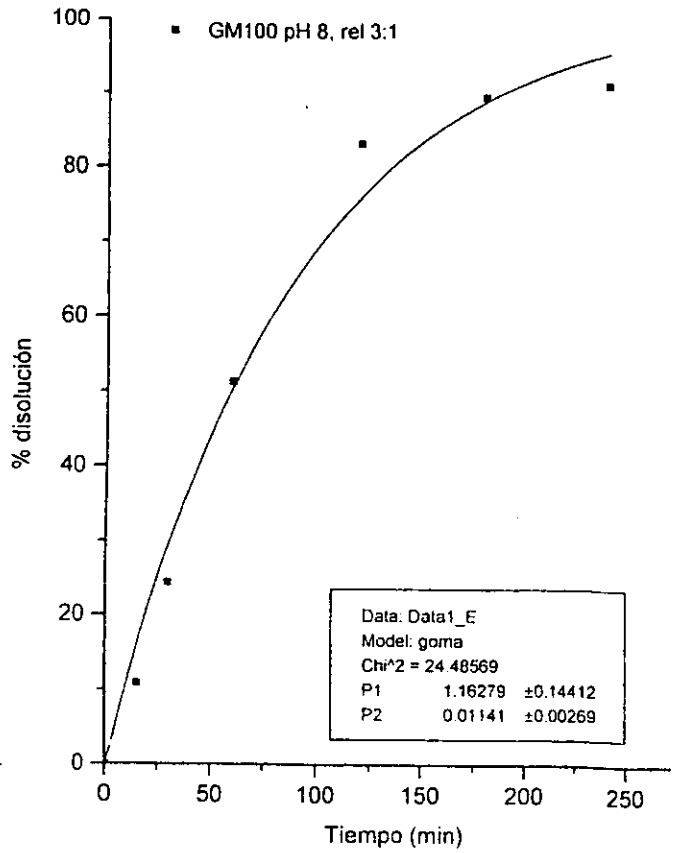
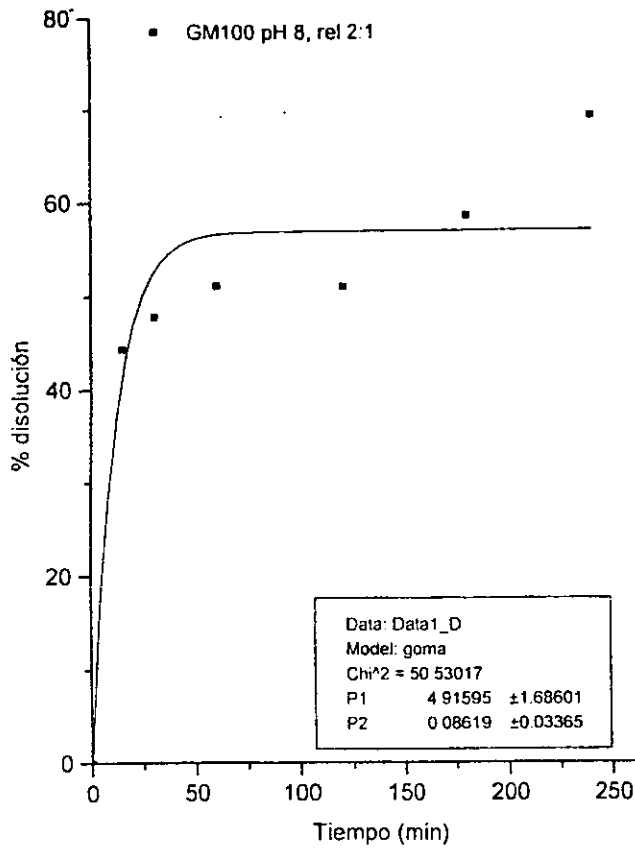
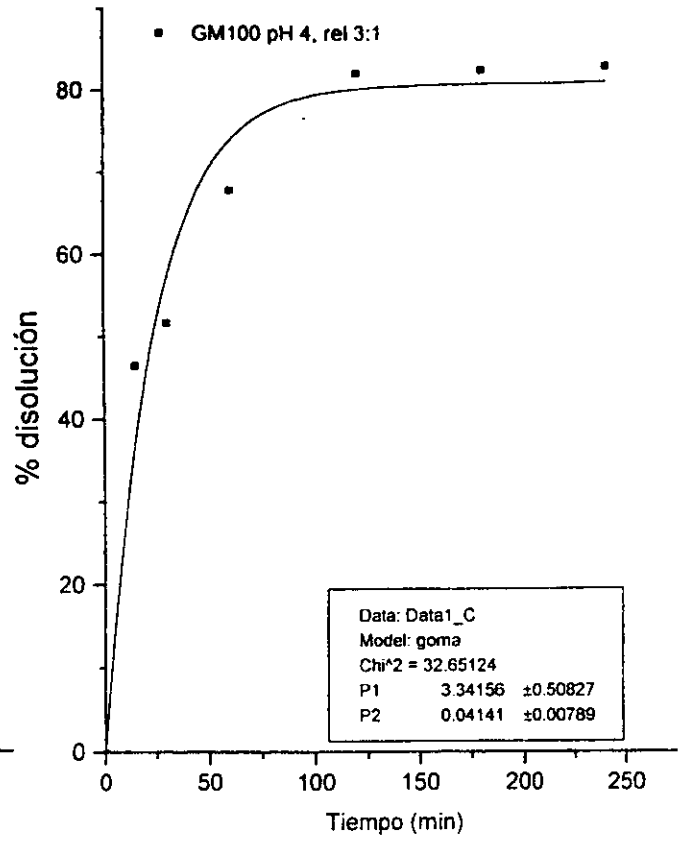
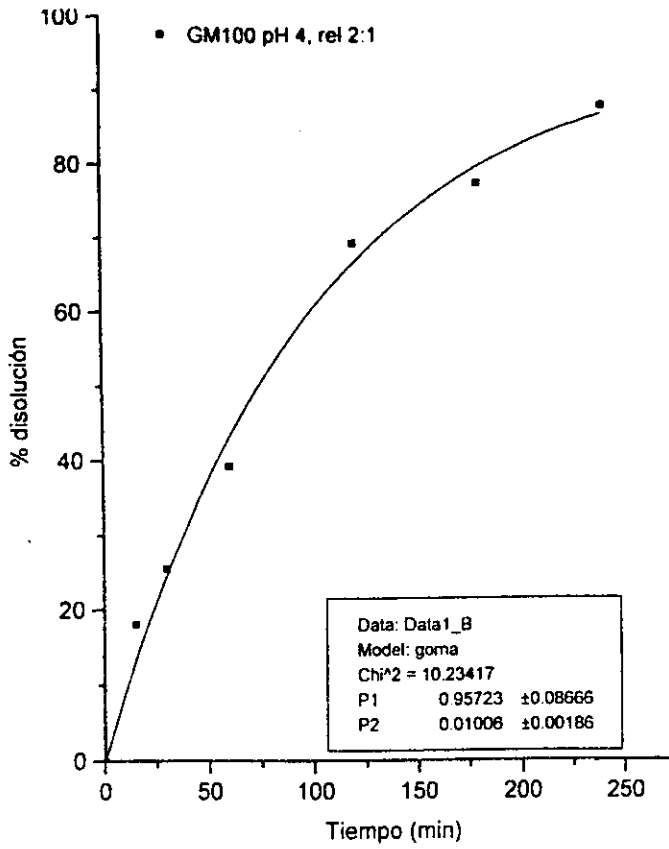
GA17-GM66-MD17 pH 8, relación 3:1

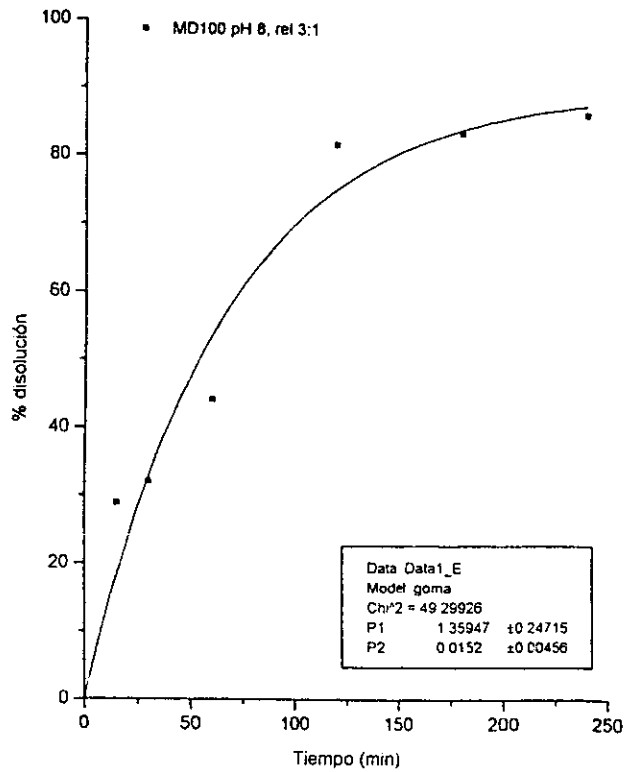
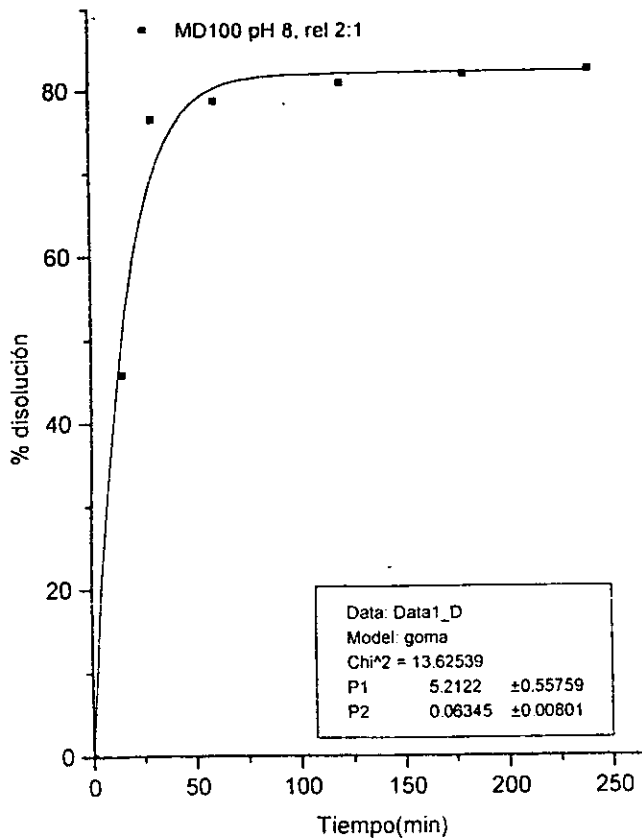
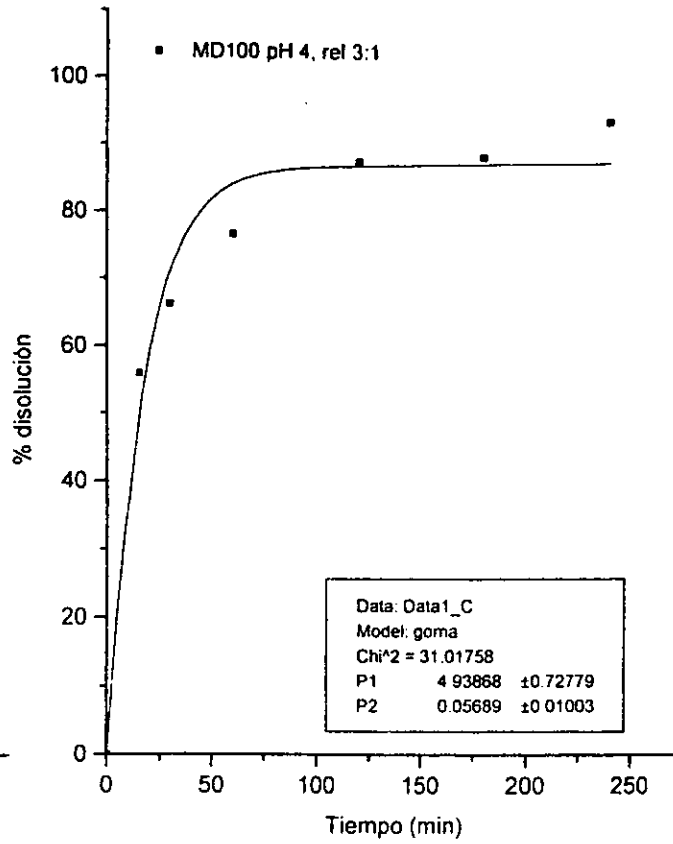
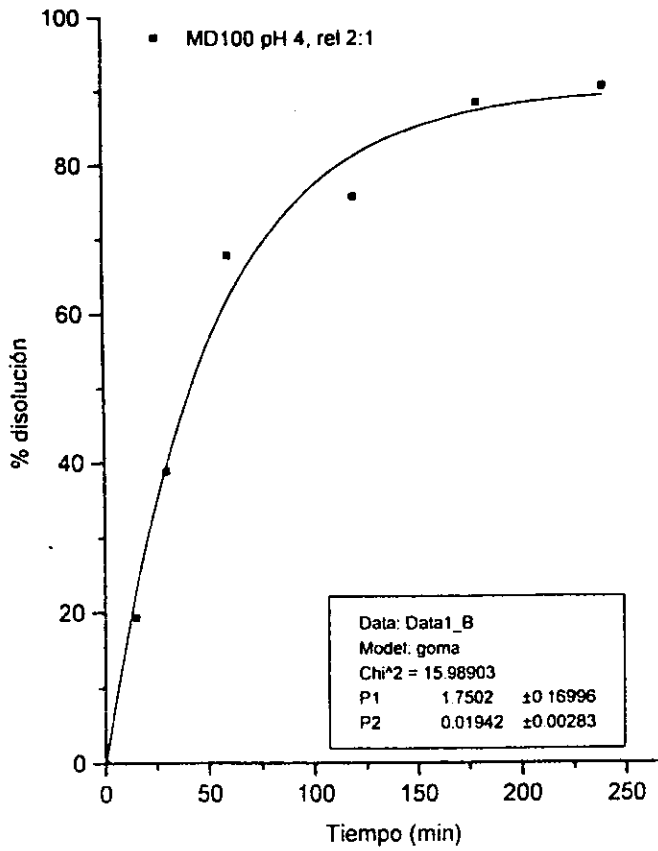


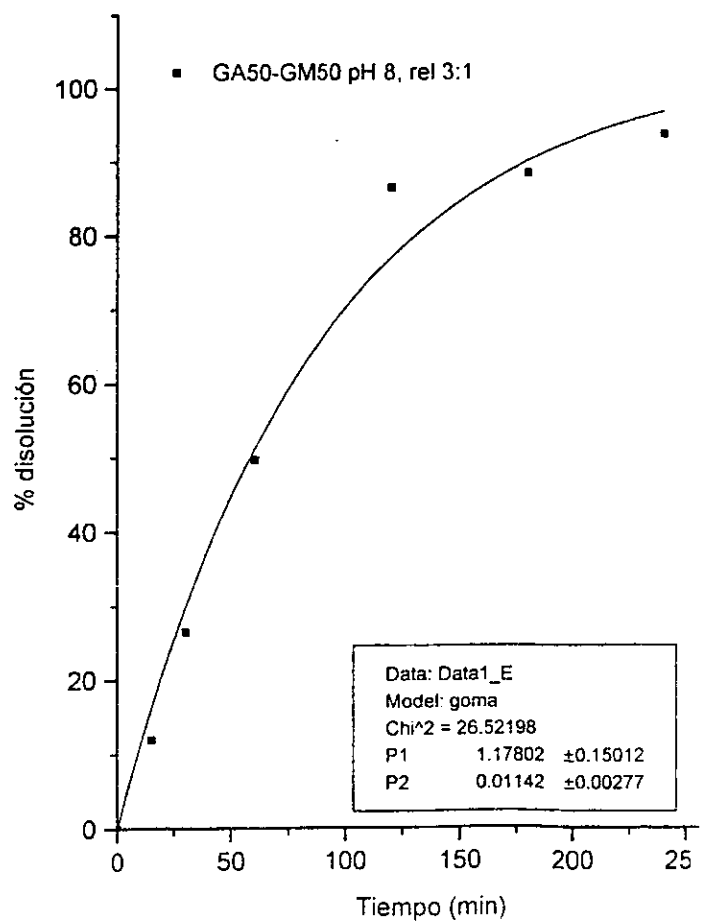
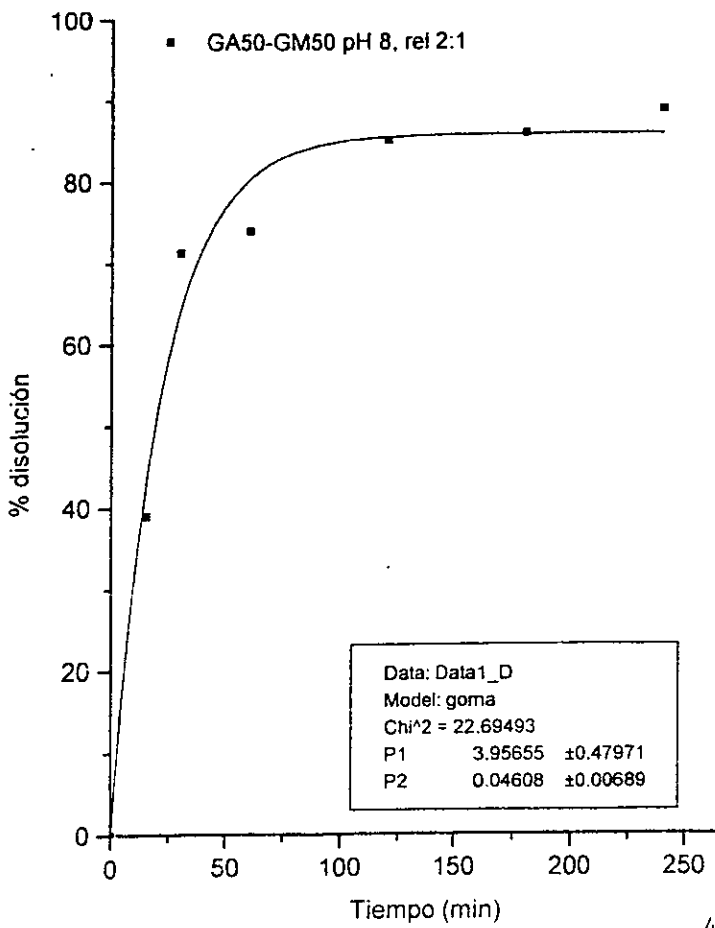
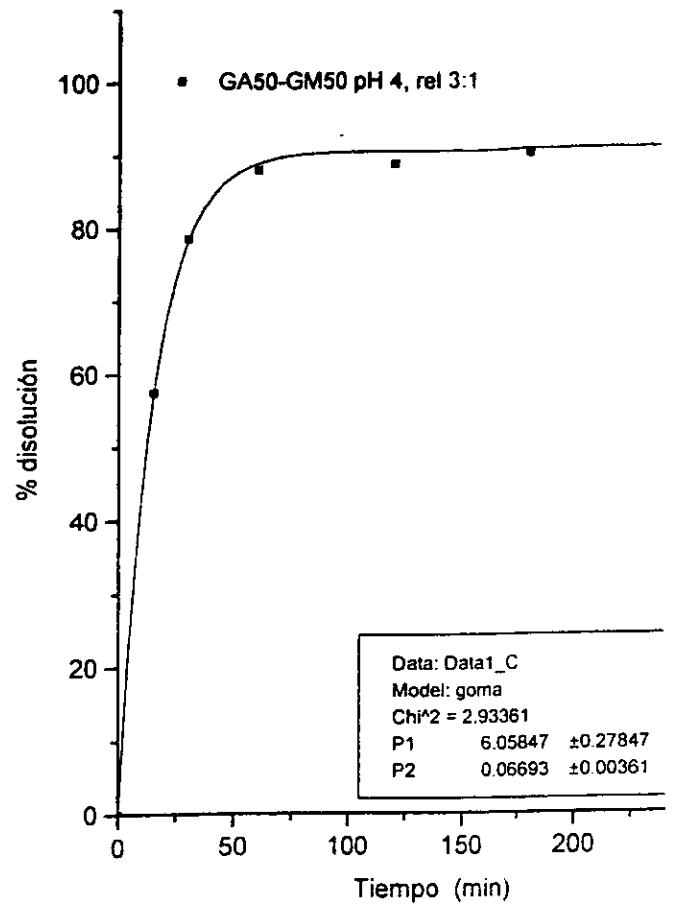
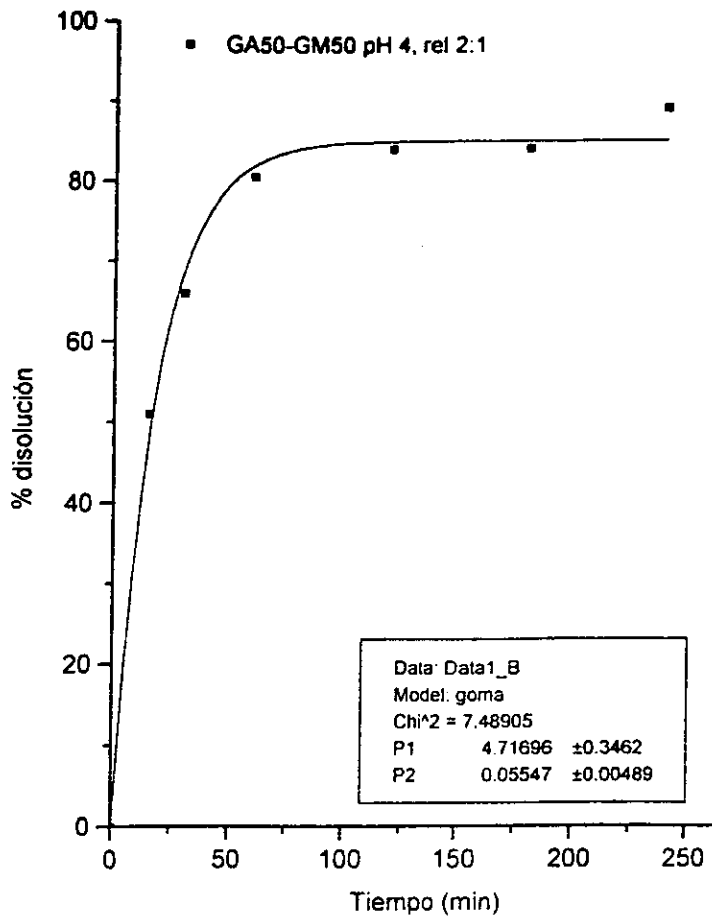
GA17-GM17-MD66 pH 8, relación 3:1

**APÉNDICE 3**  
**Gráficas de las cinéticas de disolución**

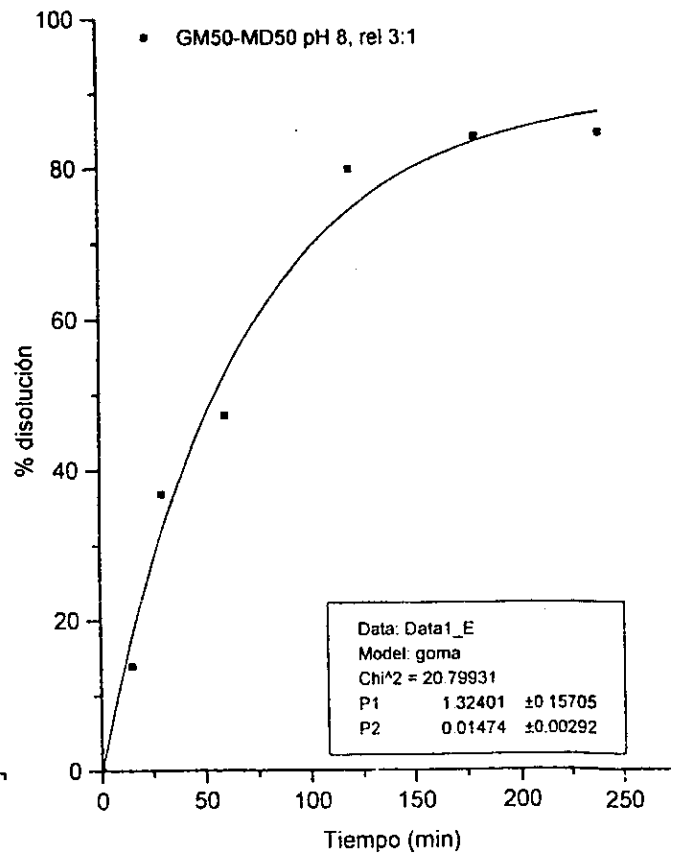
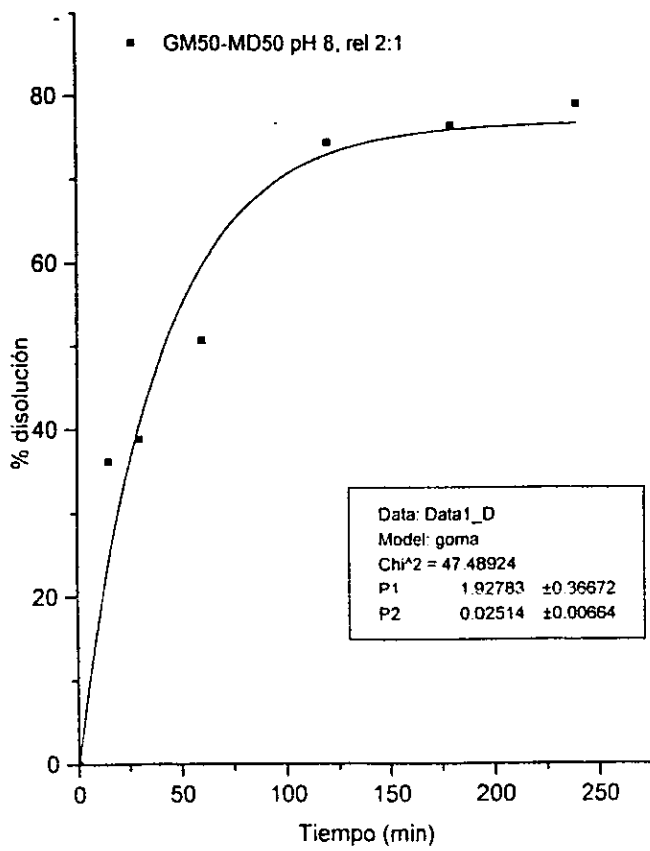
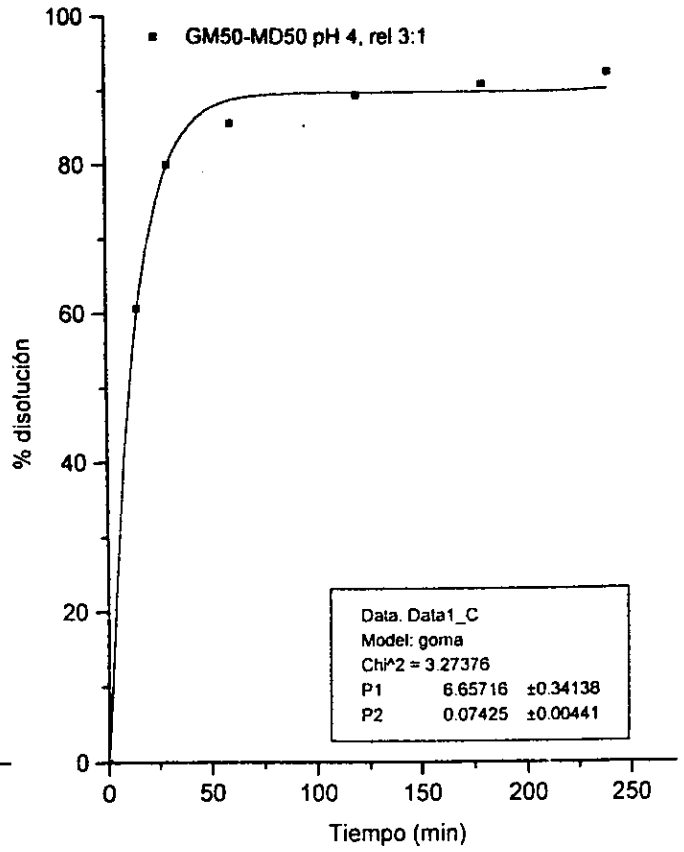
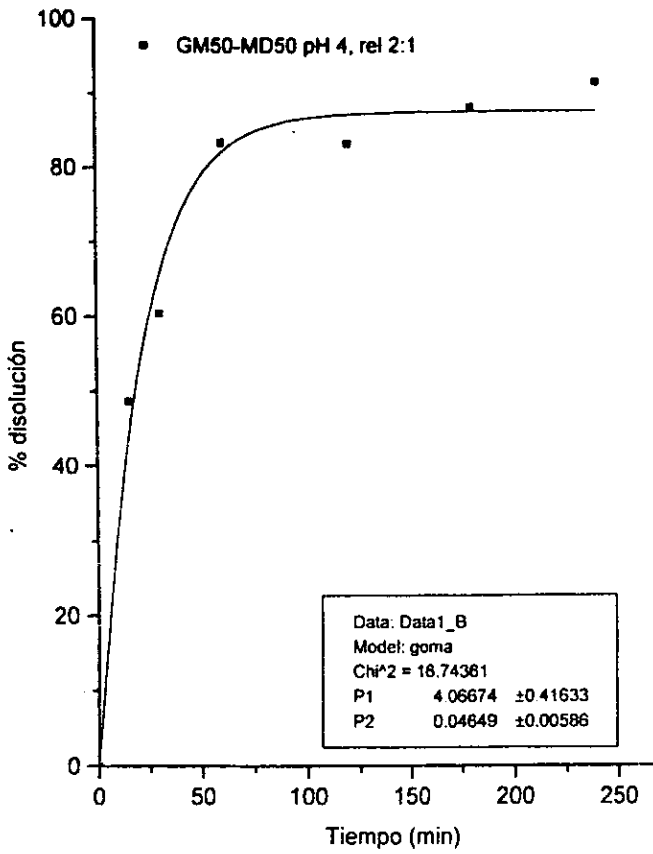


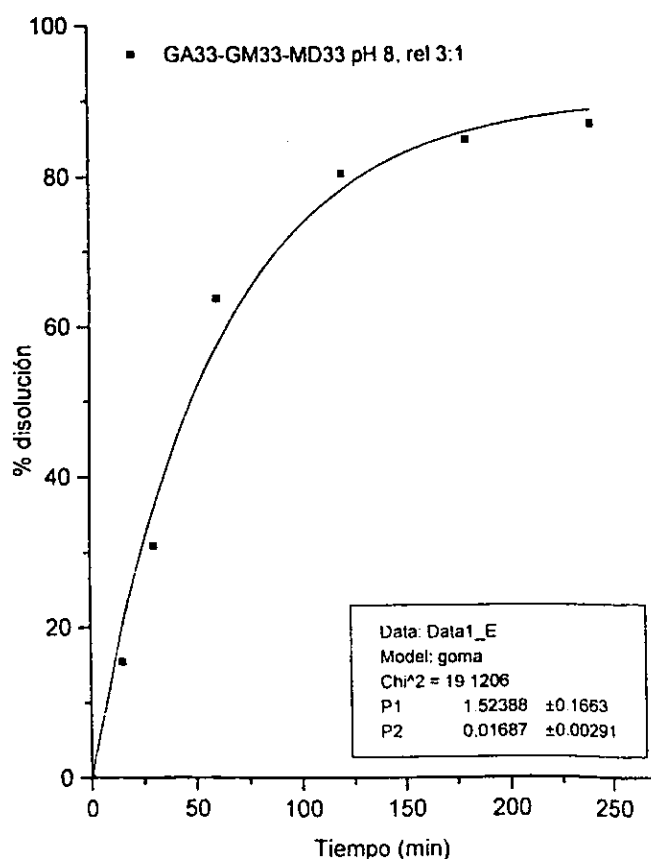
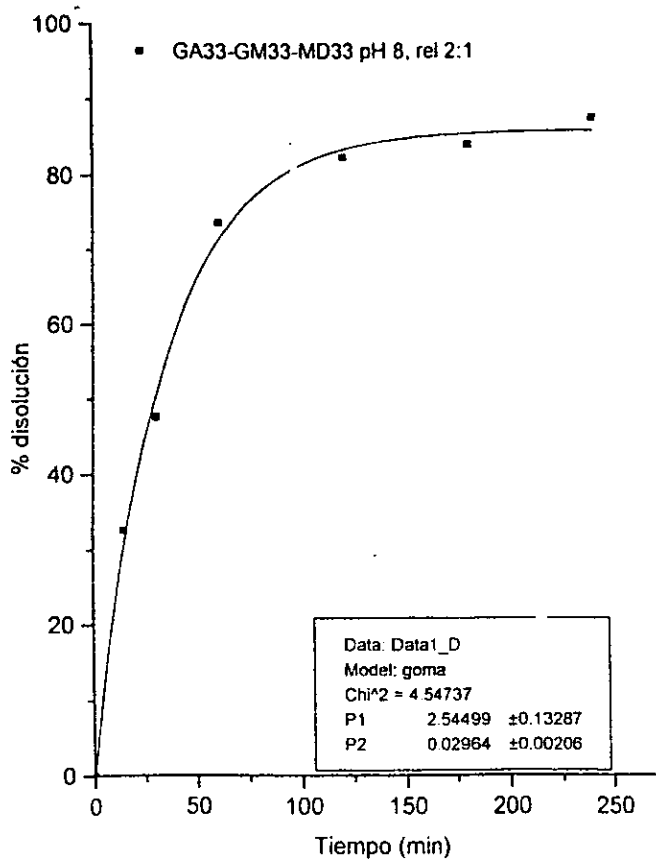
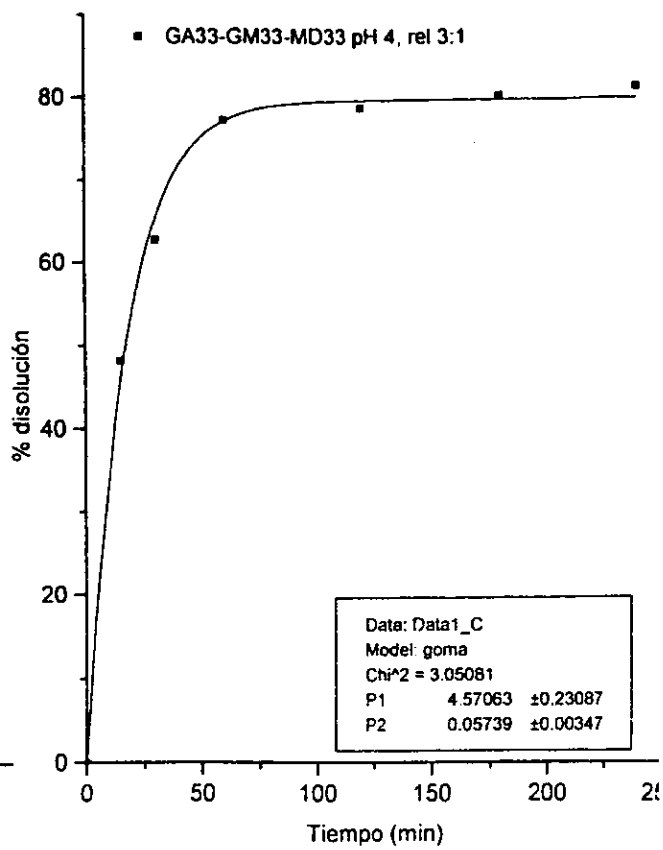
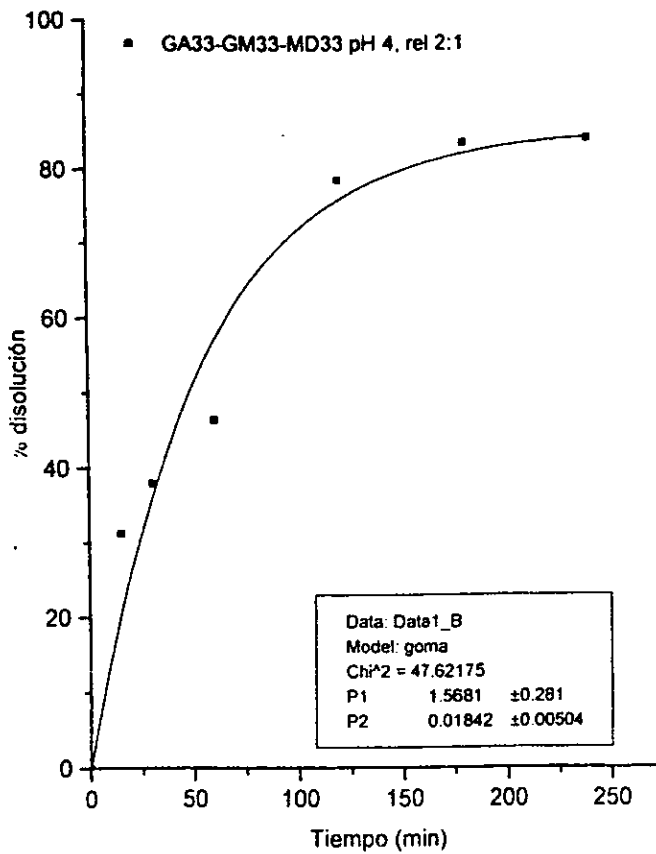


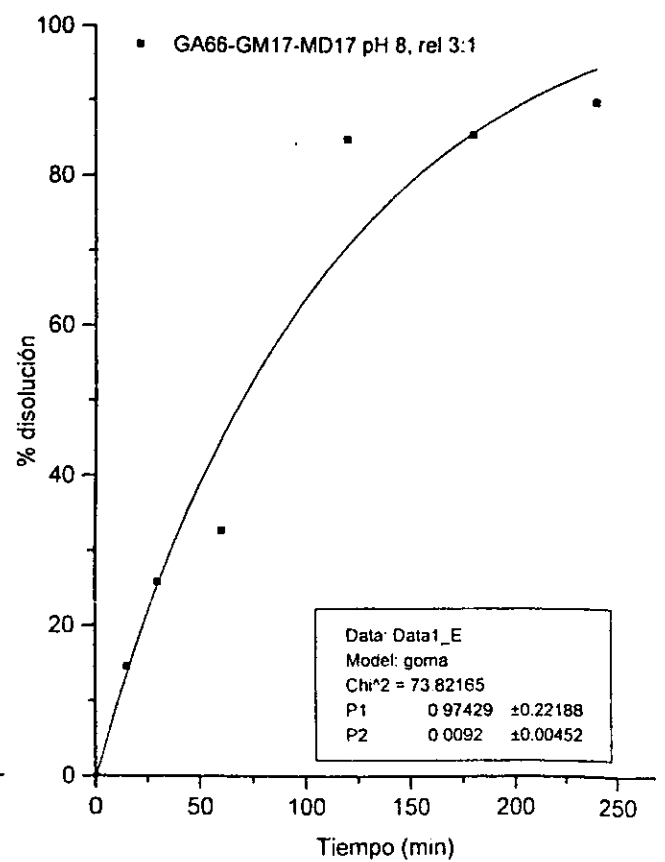
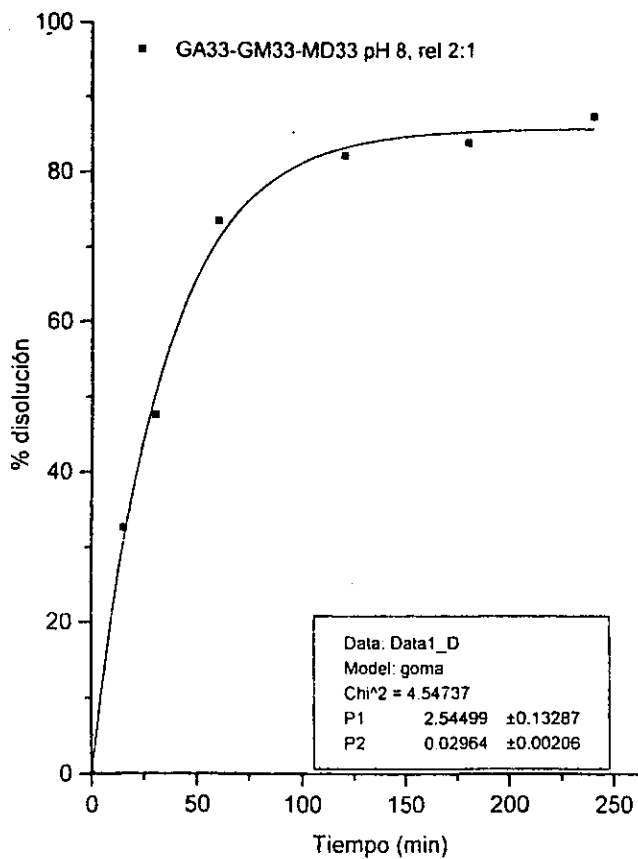
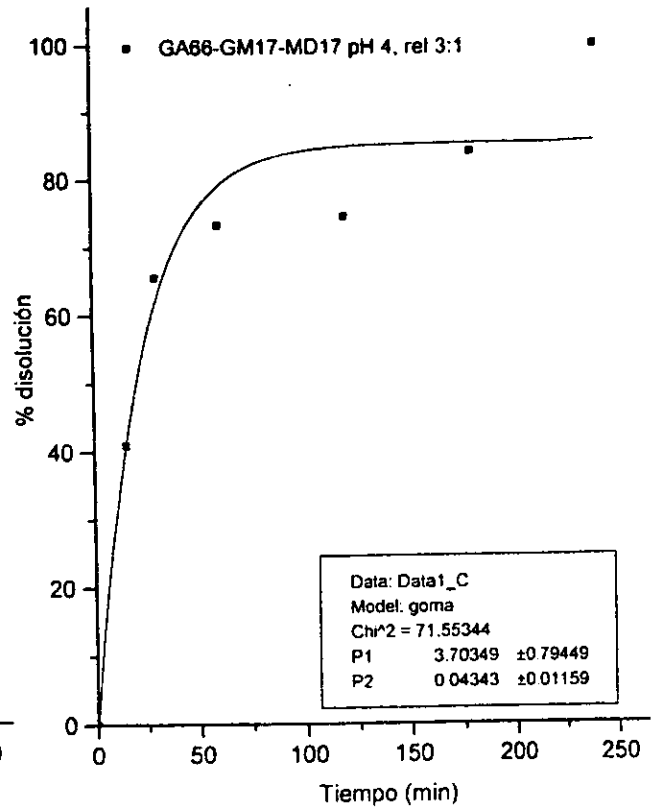
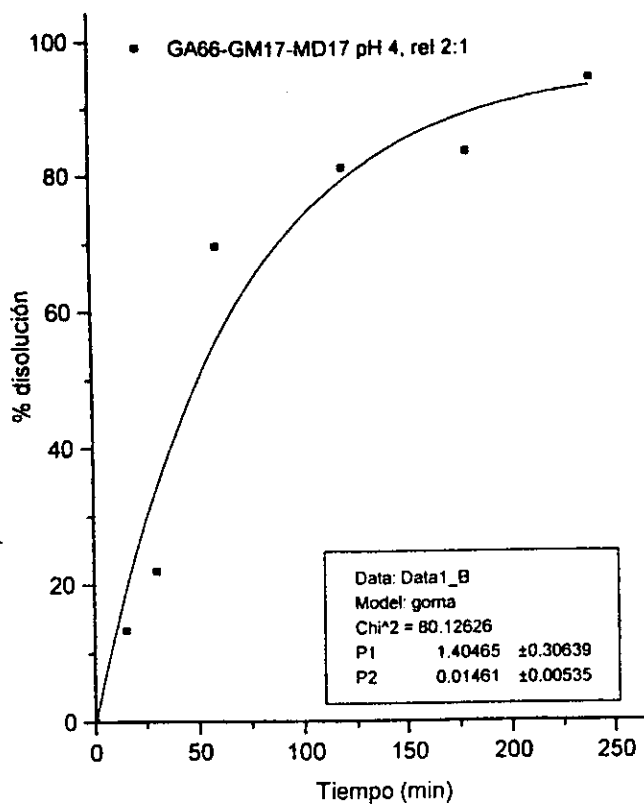


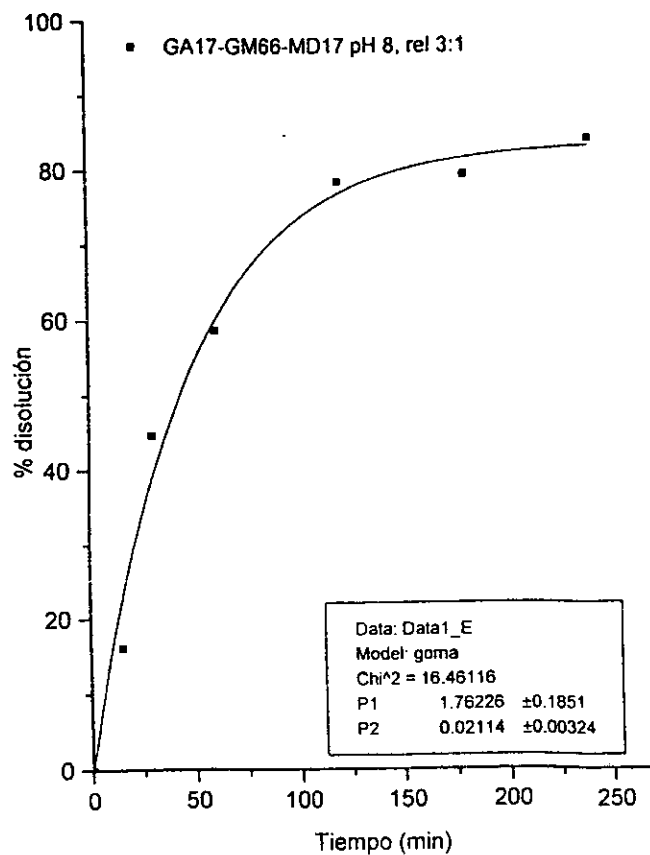
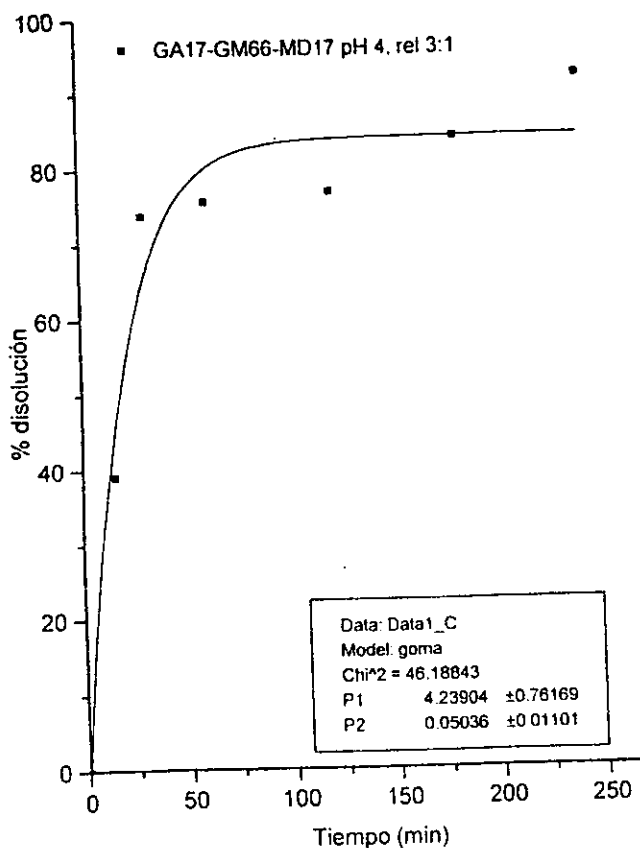
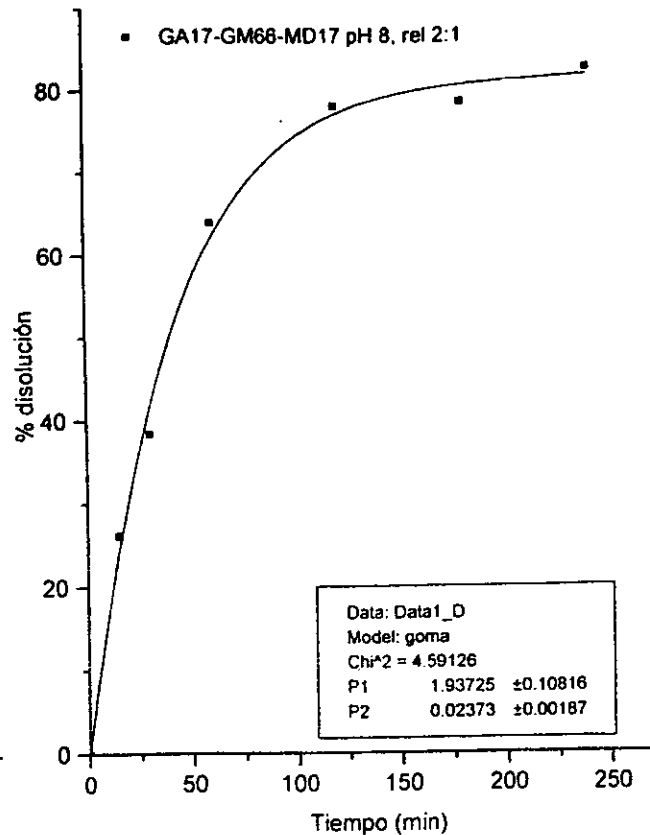
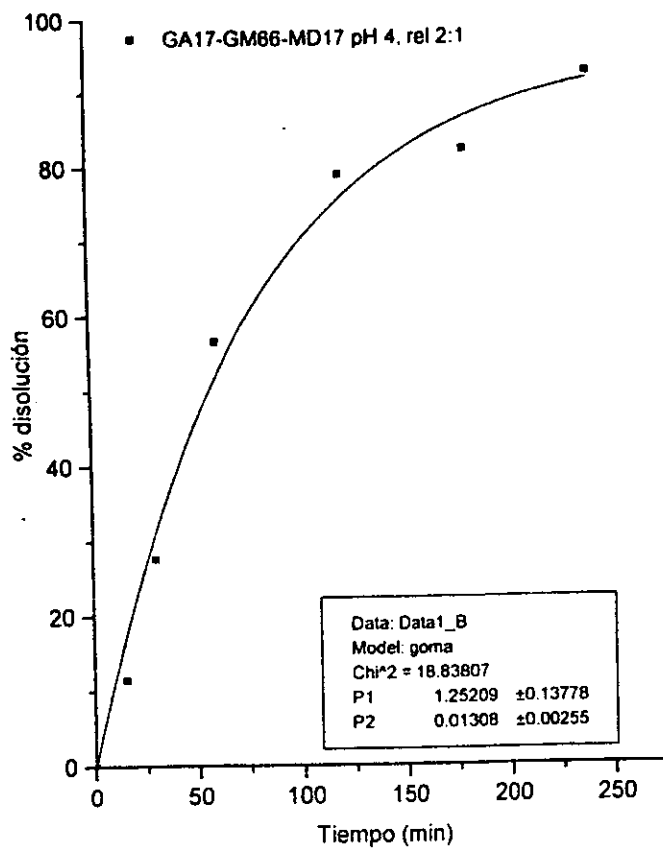


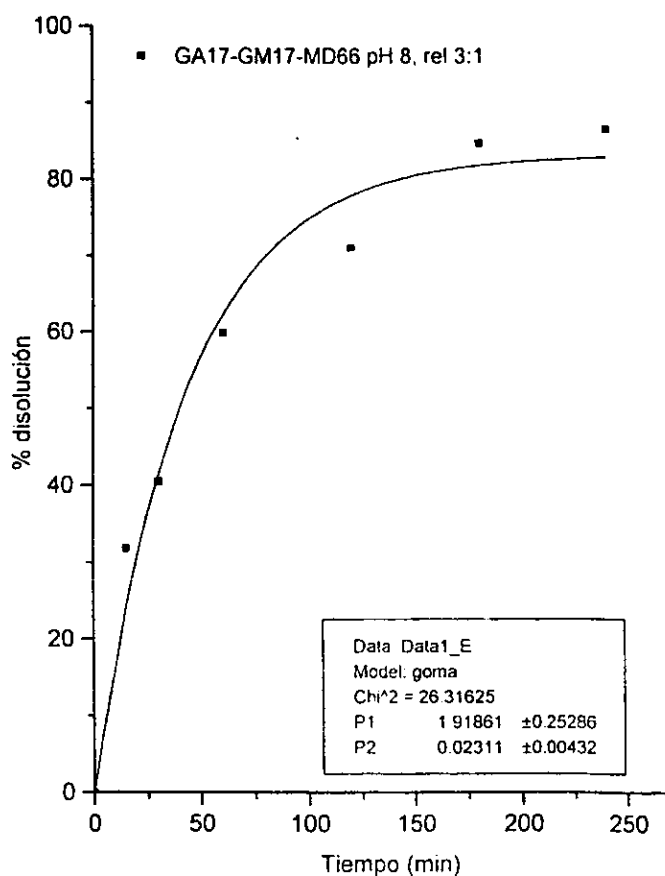
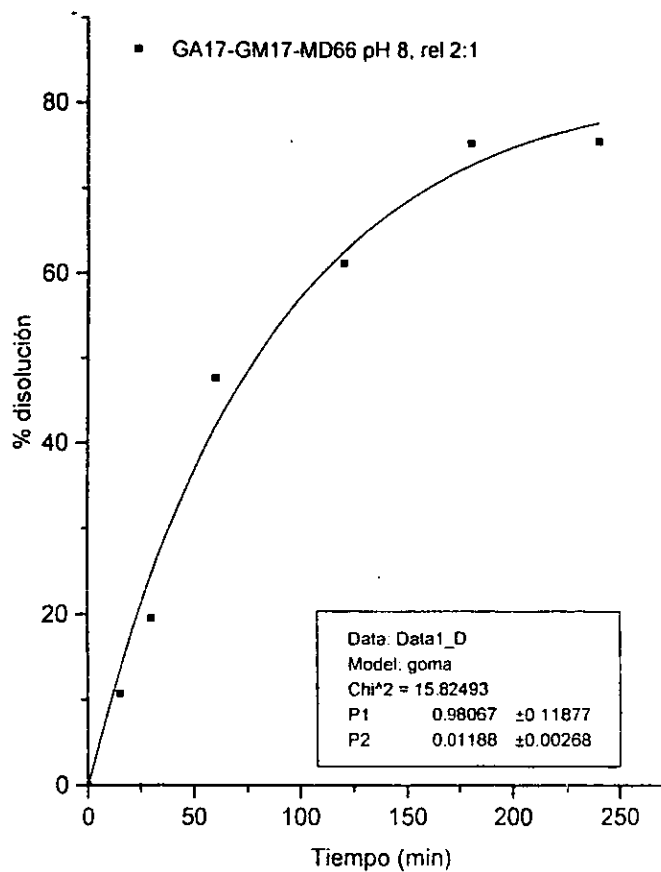
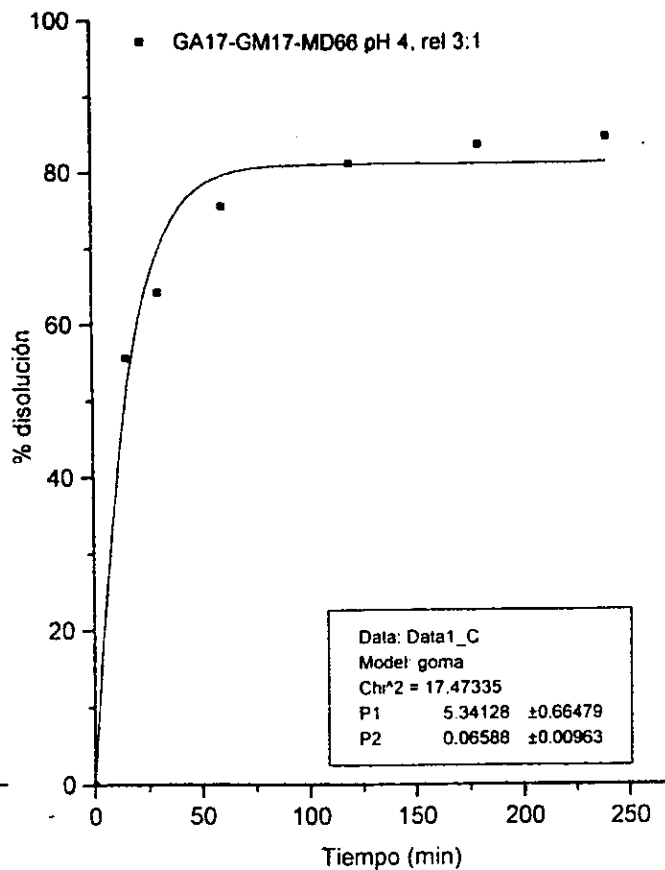
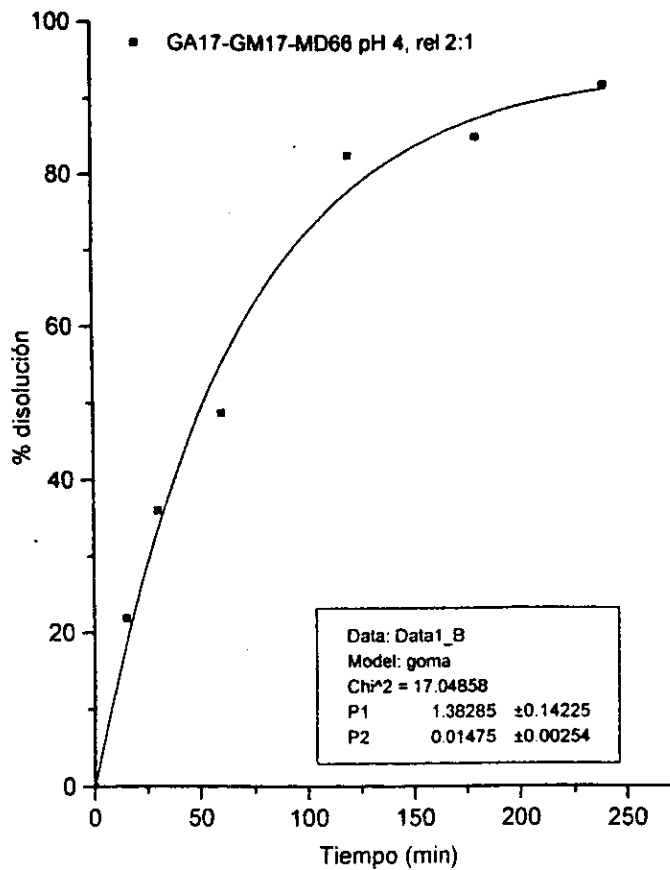


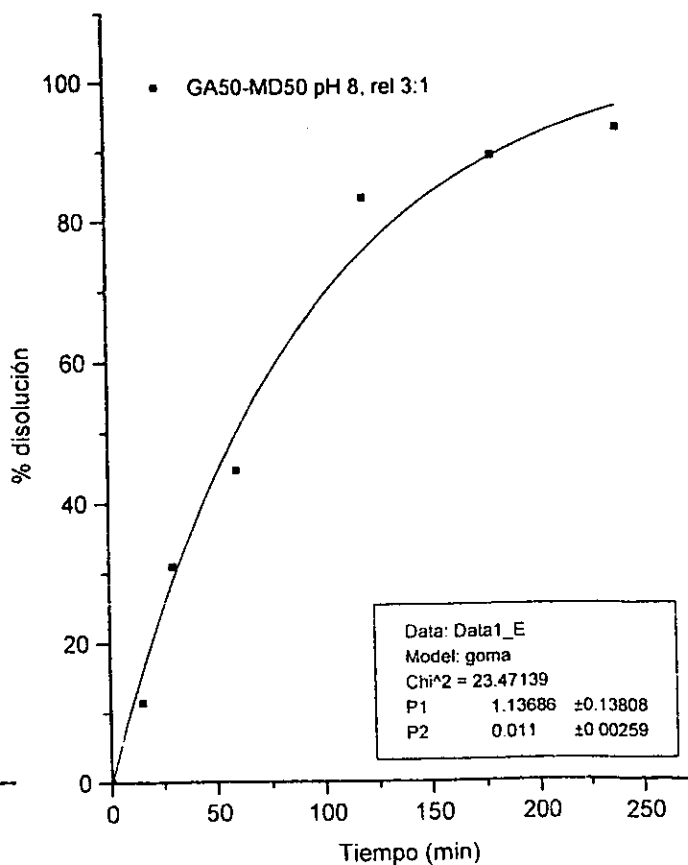
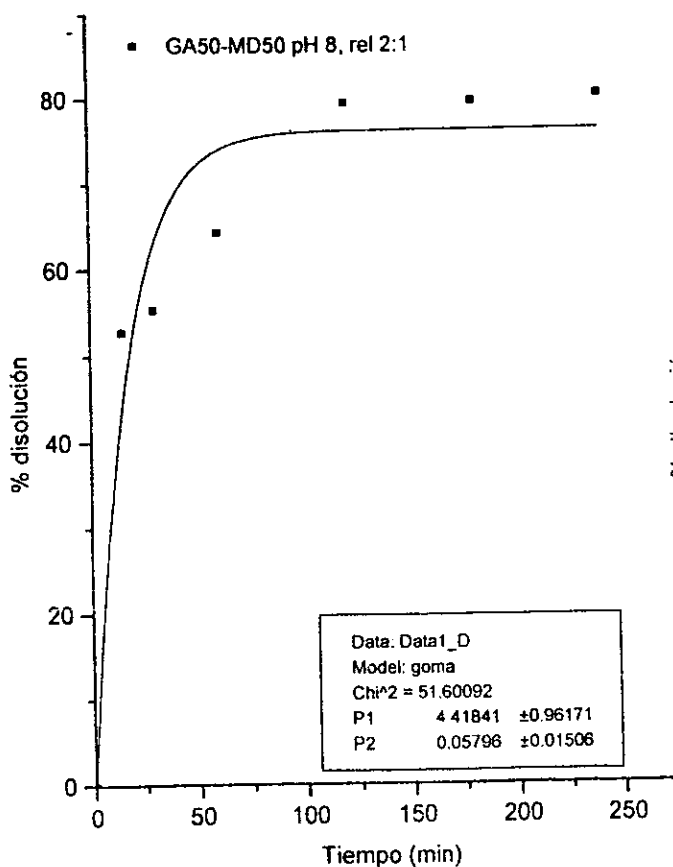
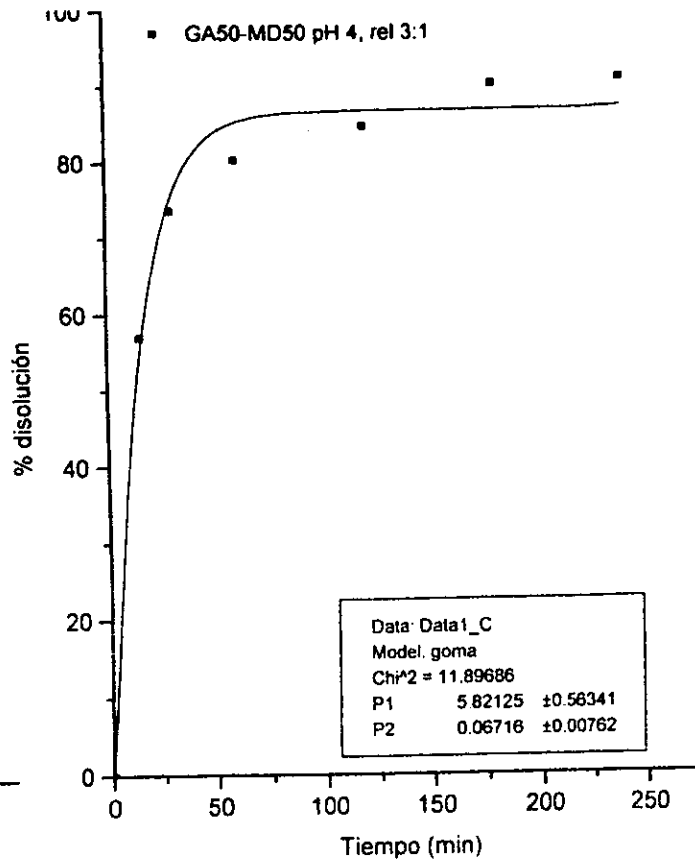
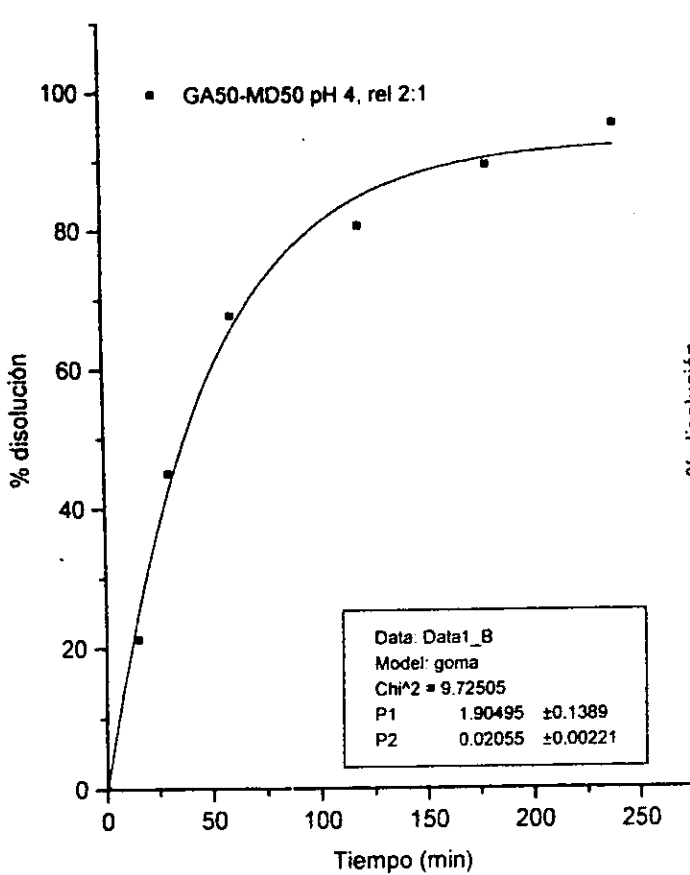




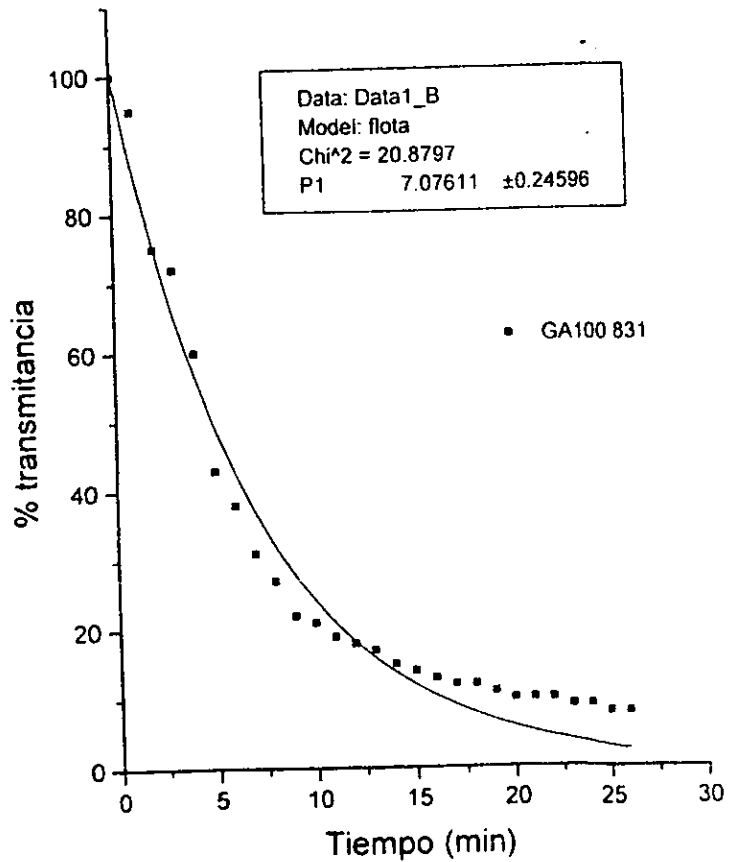
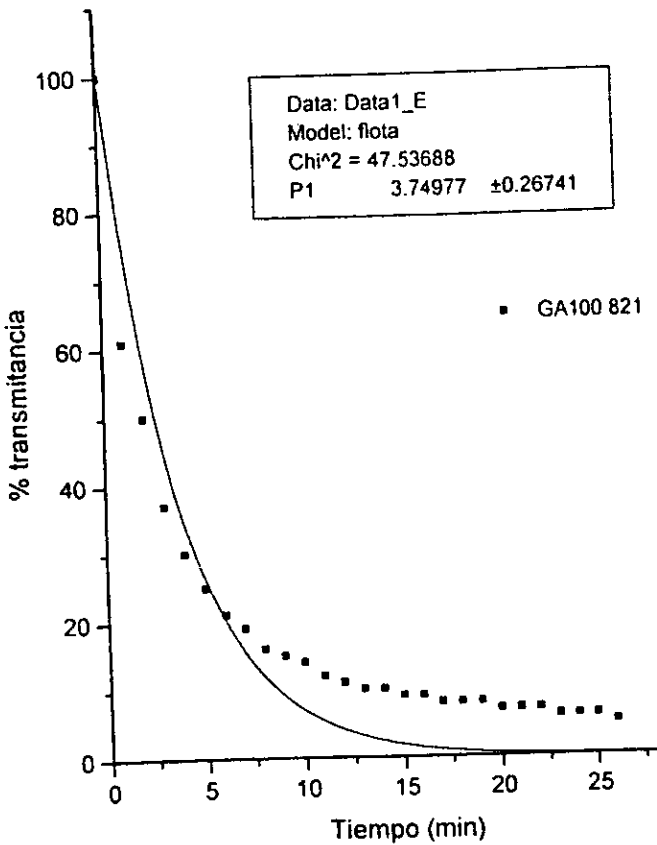
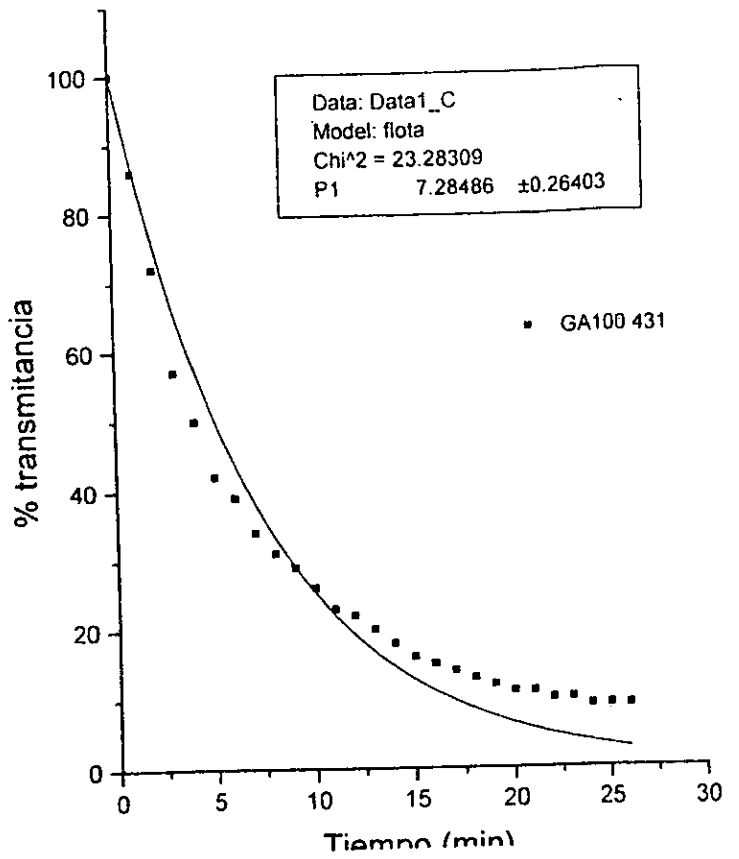
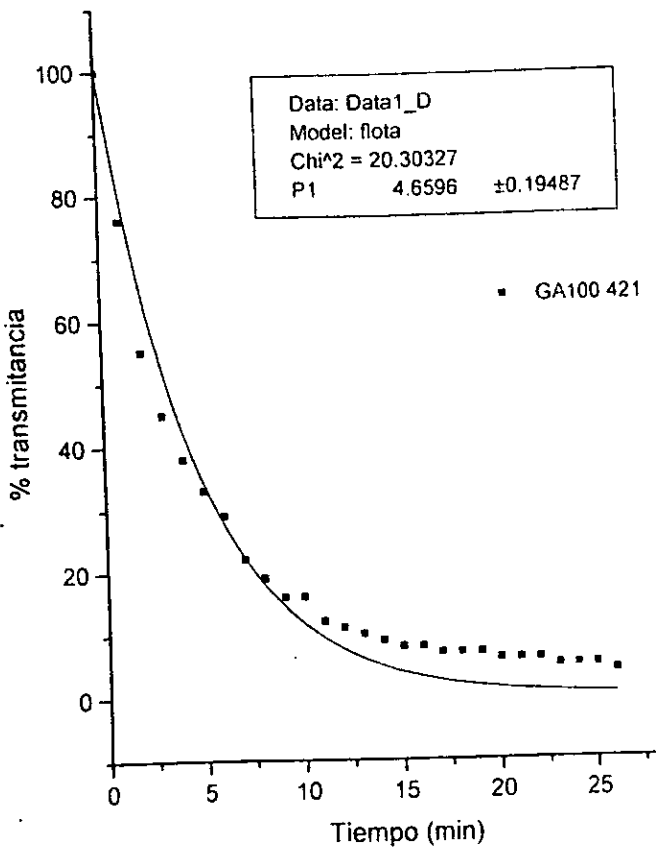




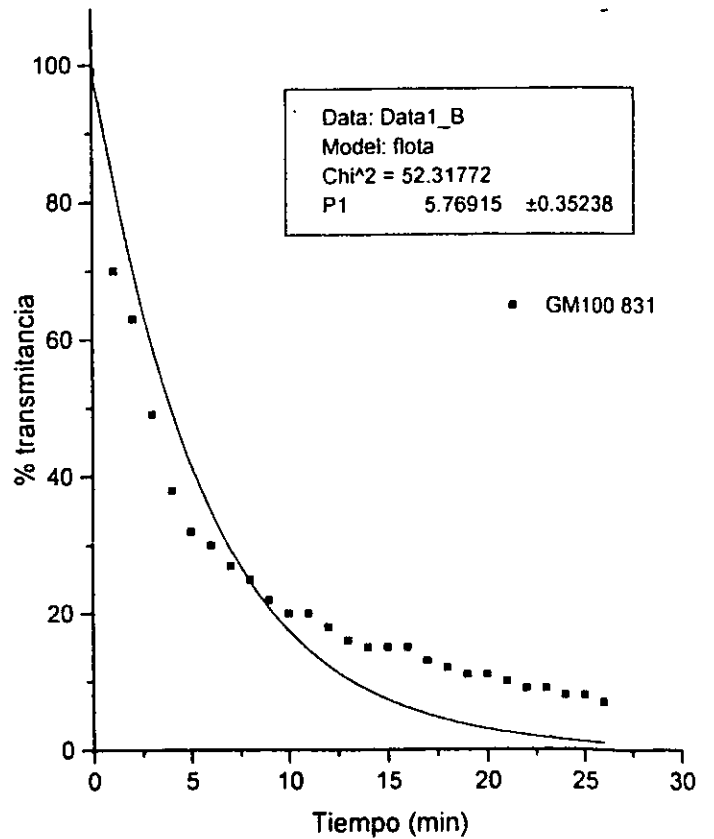
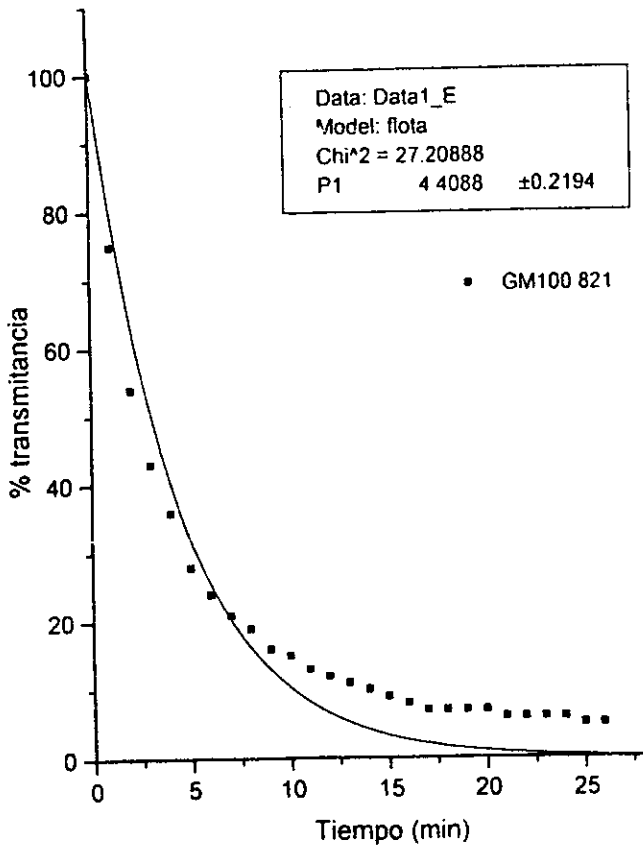
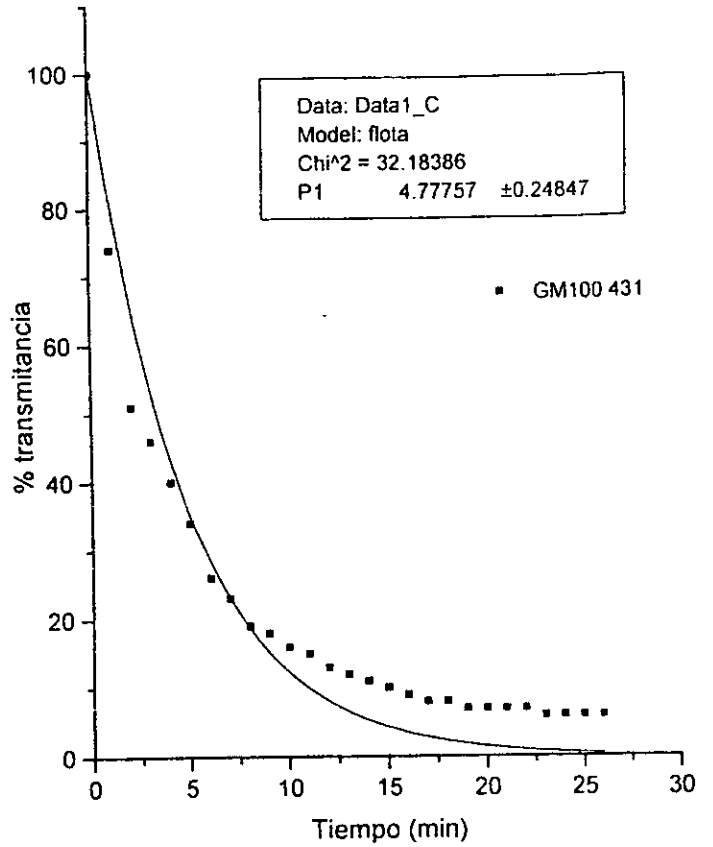
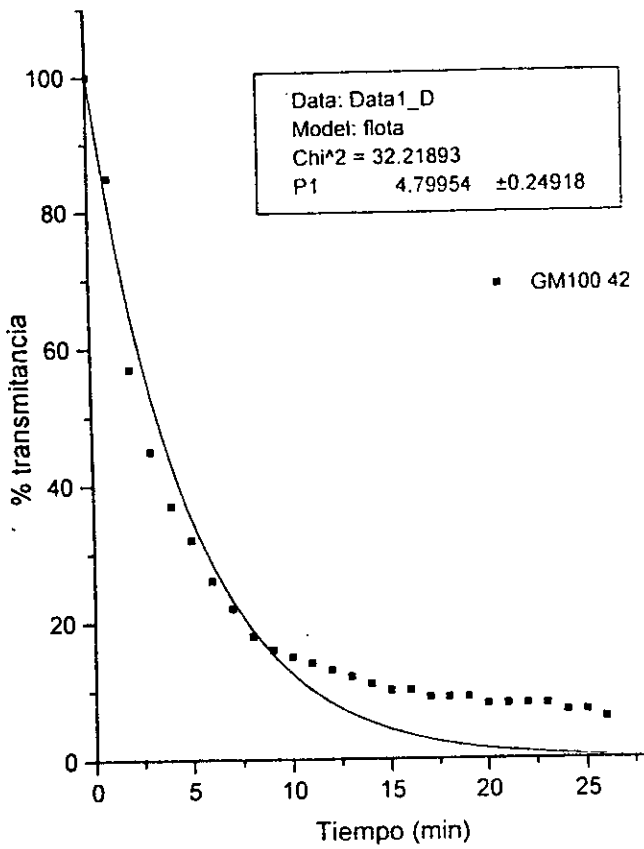


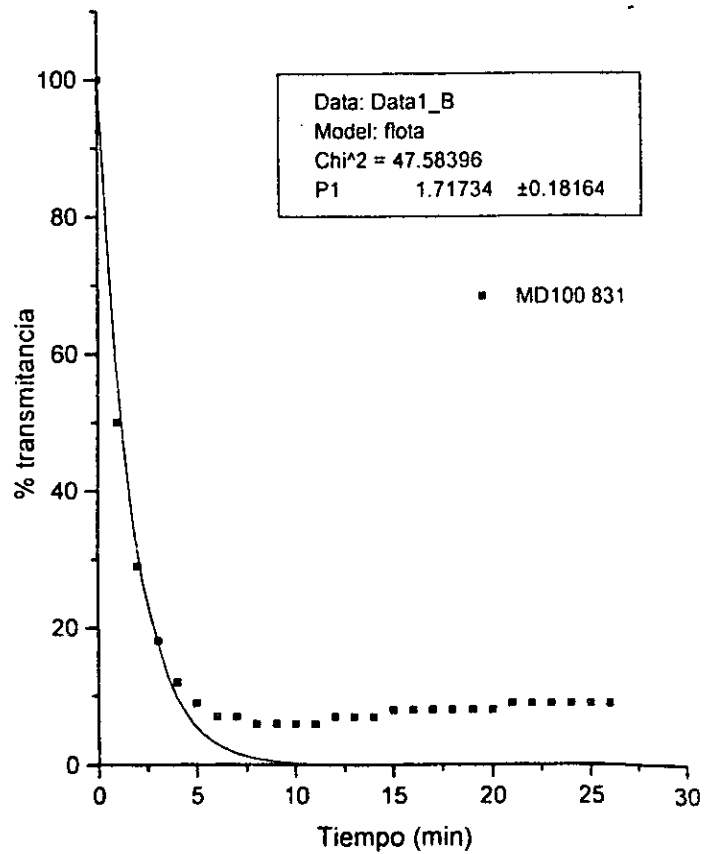
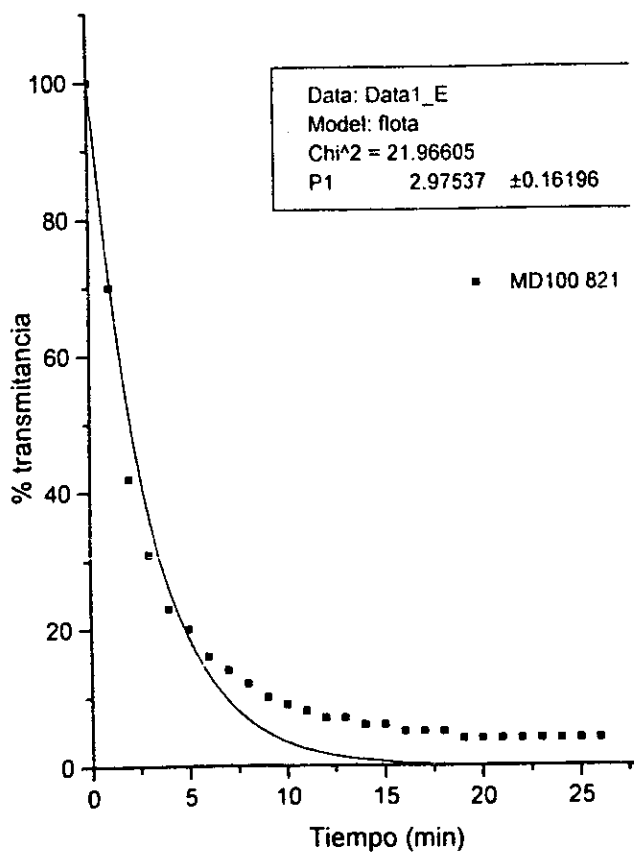
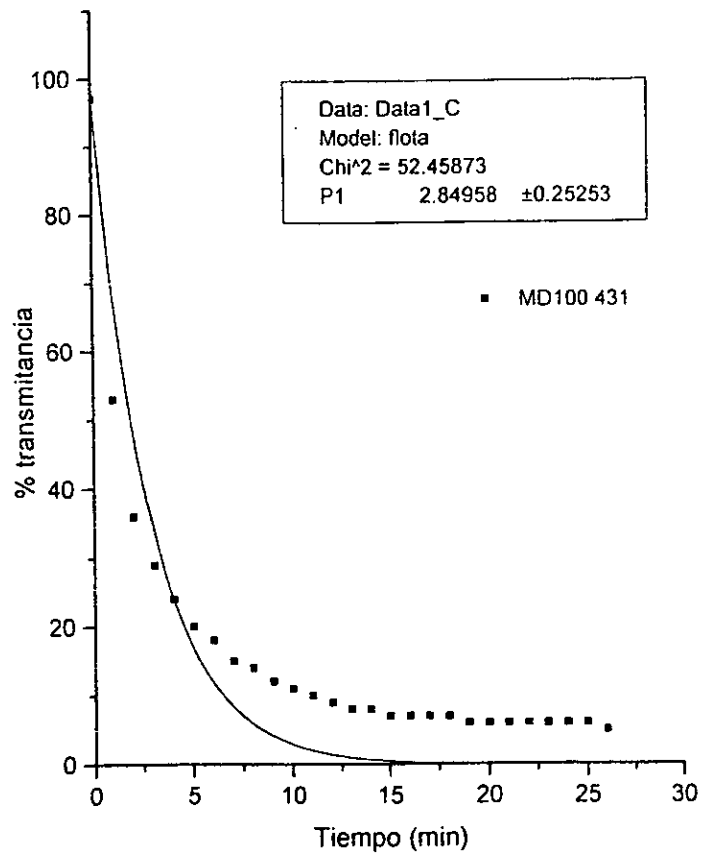
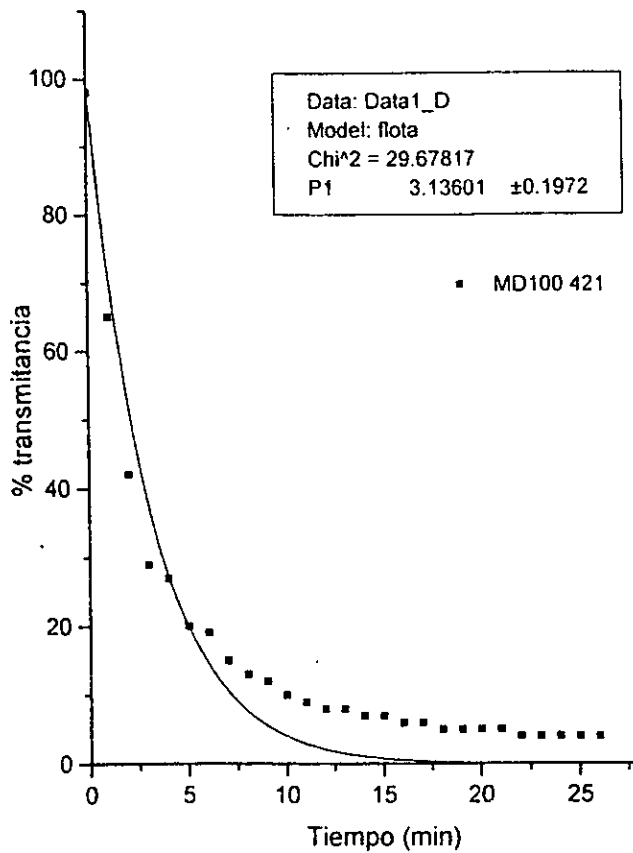


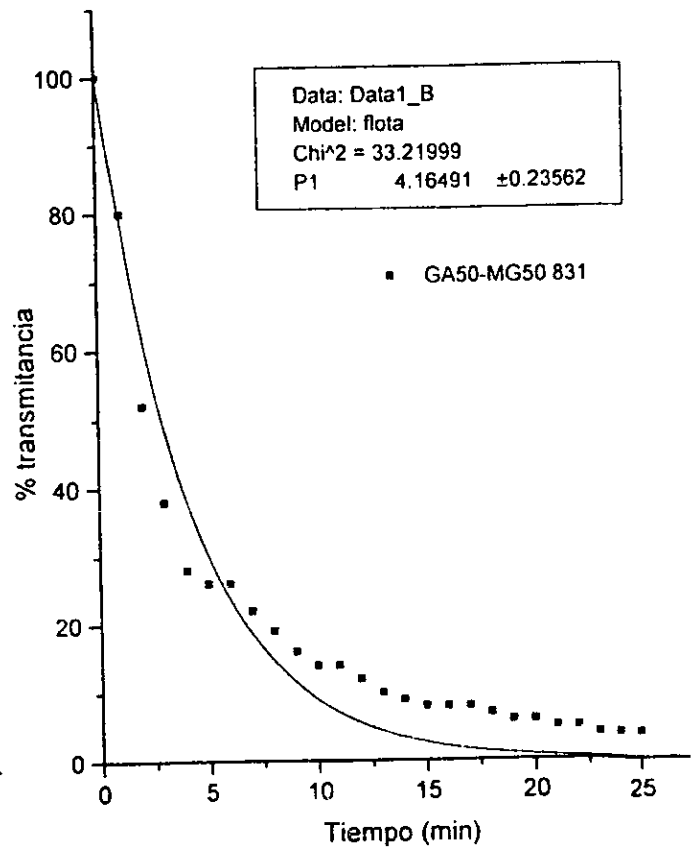
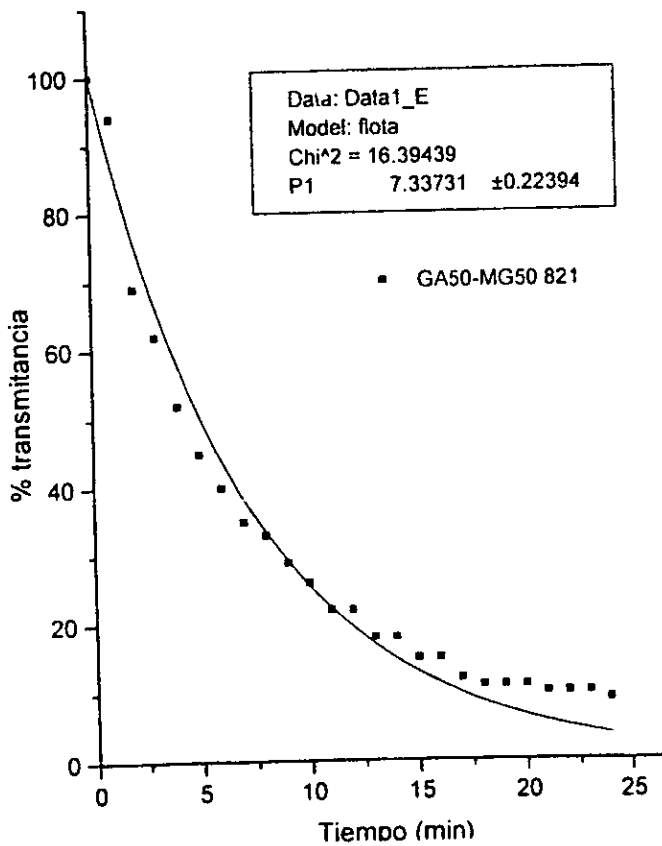
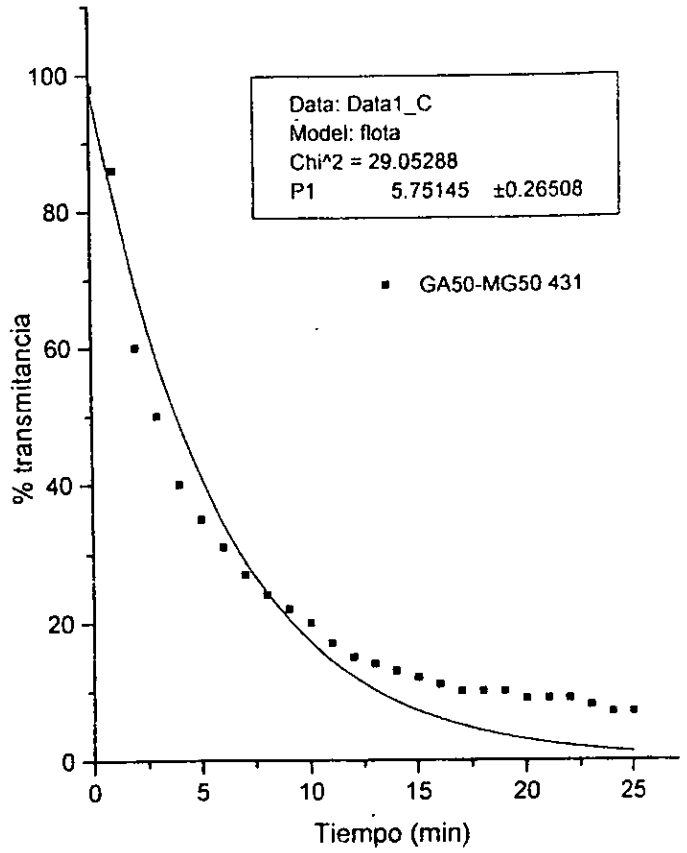
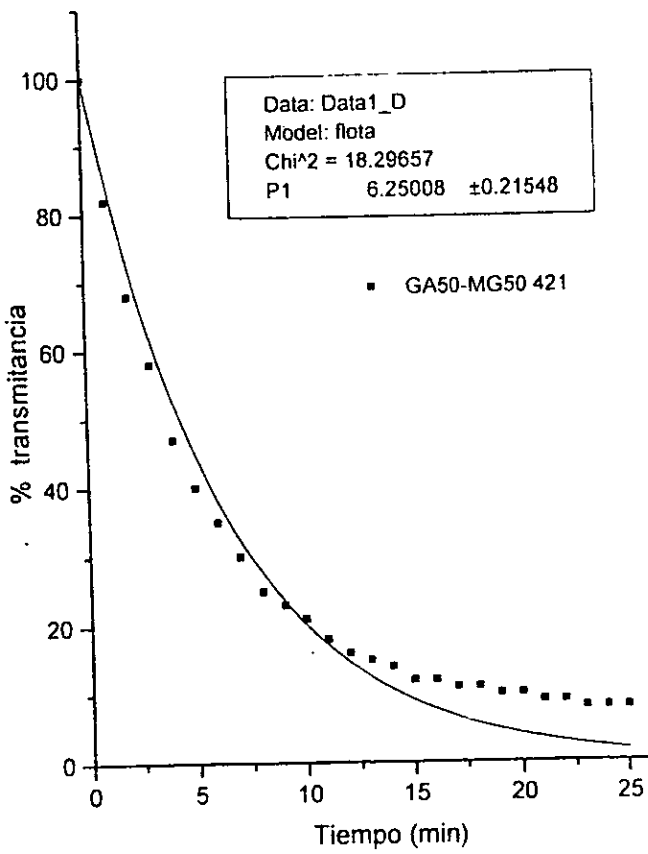
**APÉNDICE 4**  
**Gráficas de las cinéticas de flotabilidad**

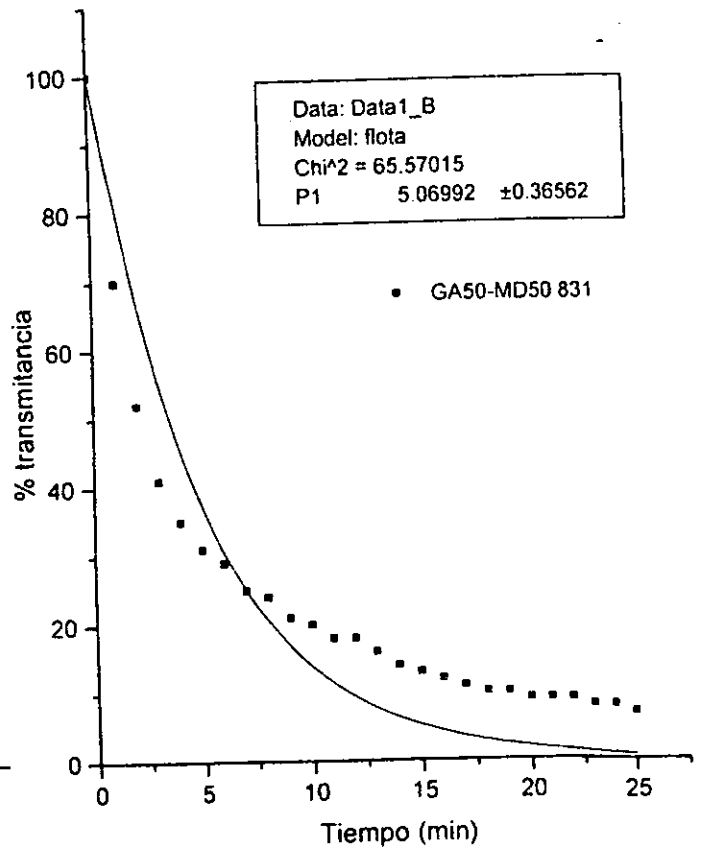
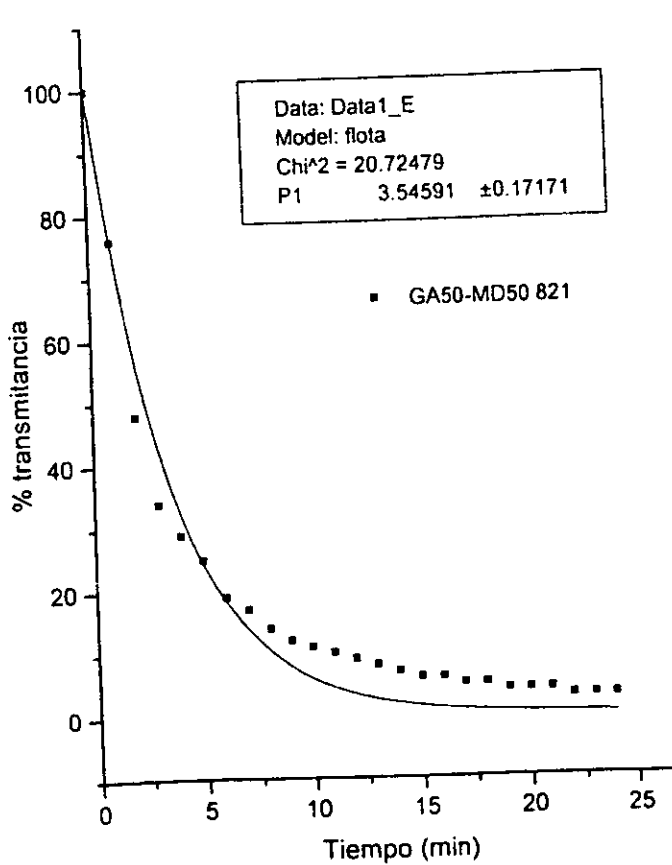
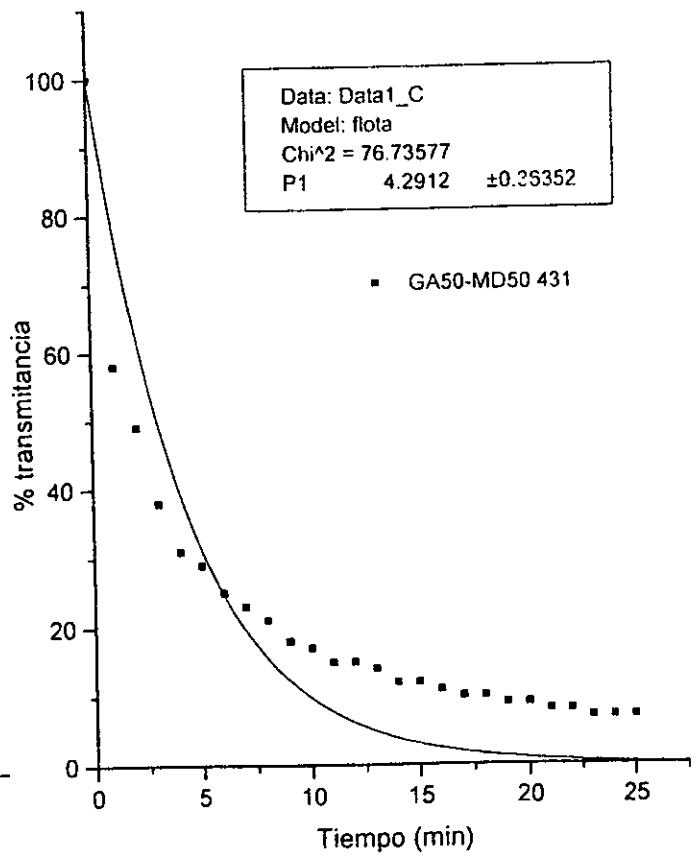
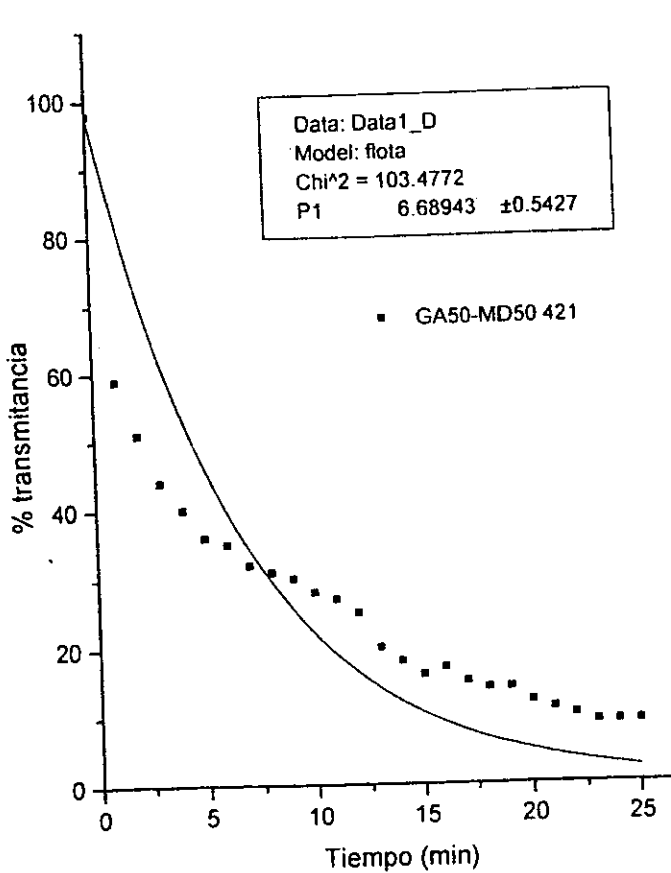


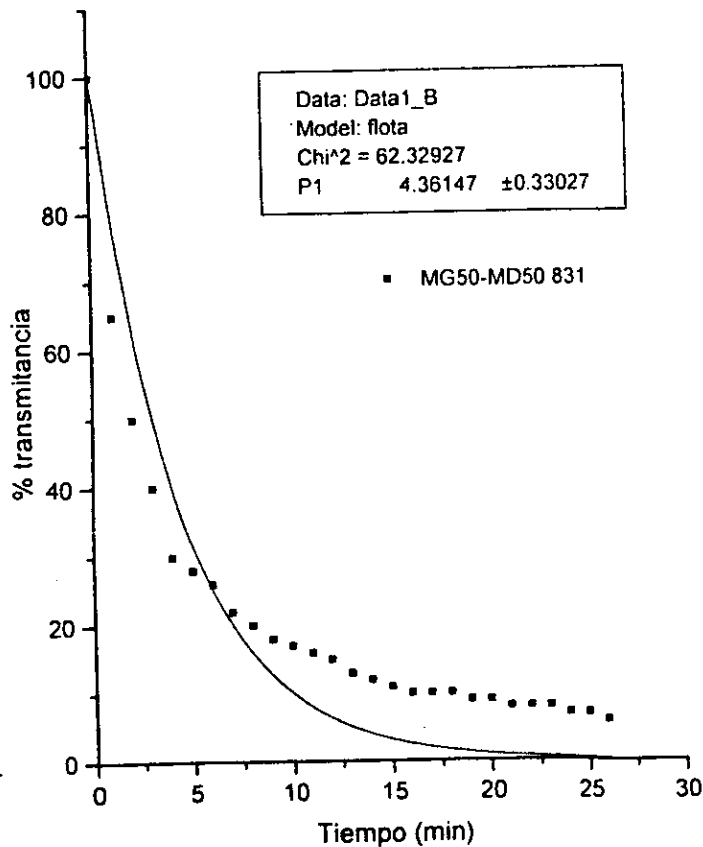
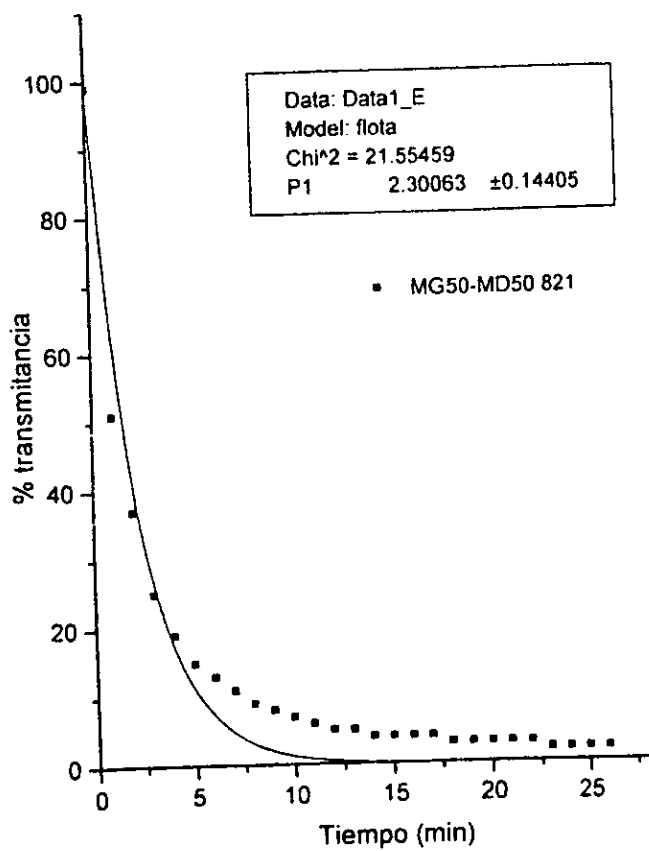
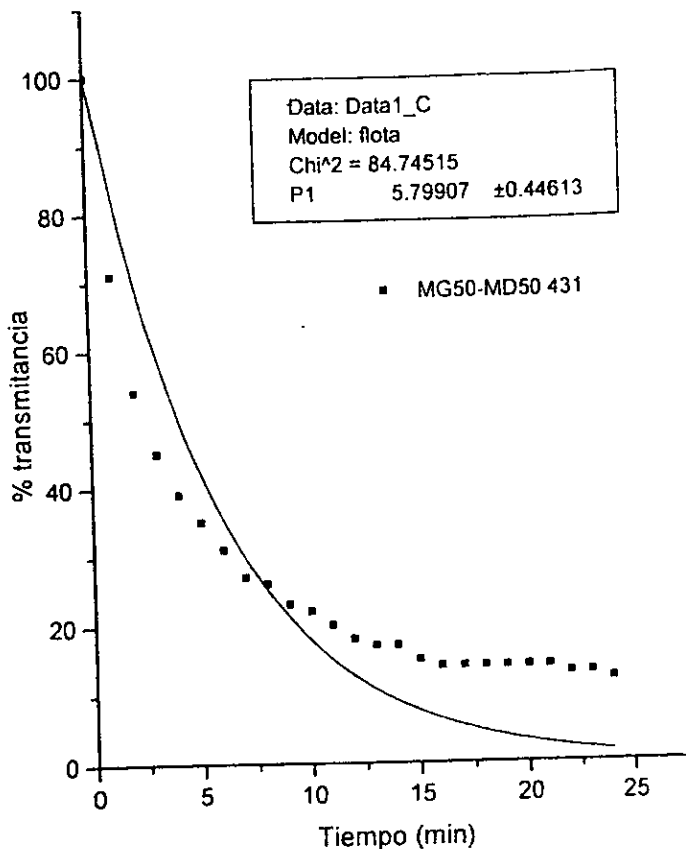
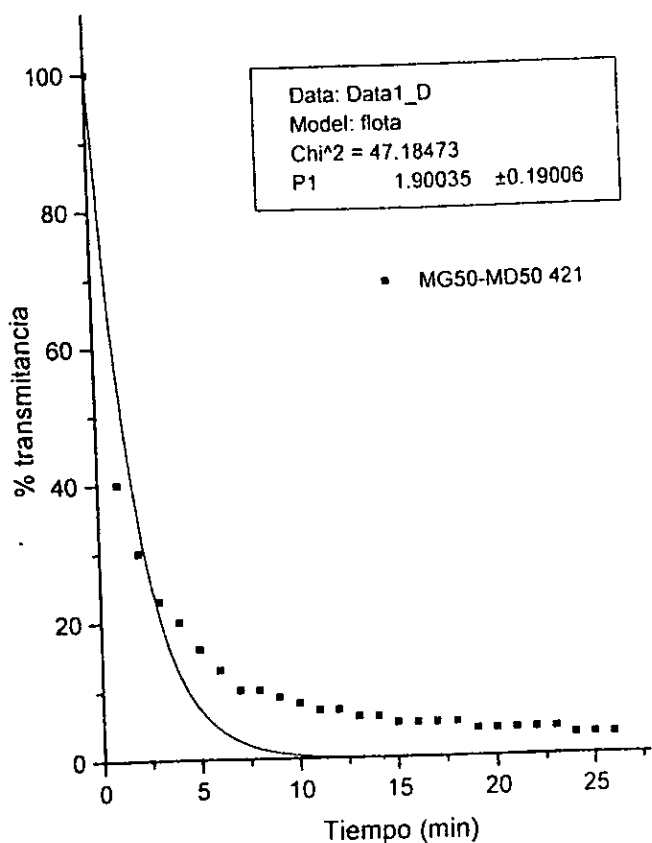


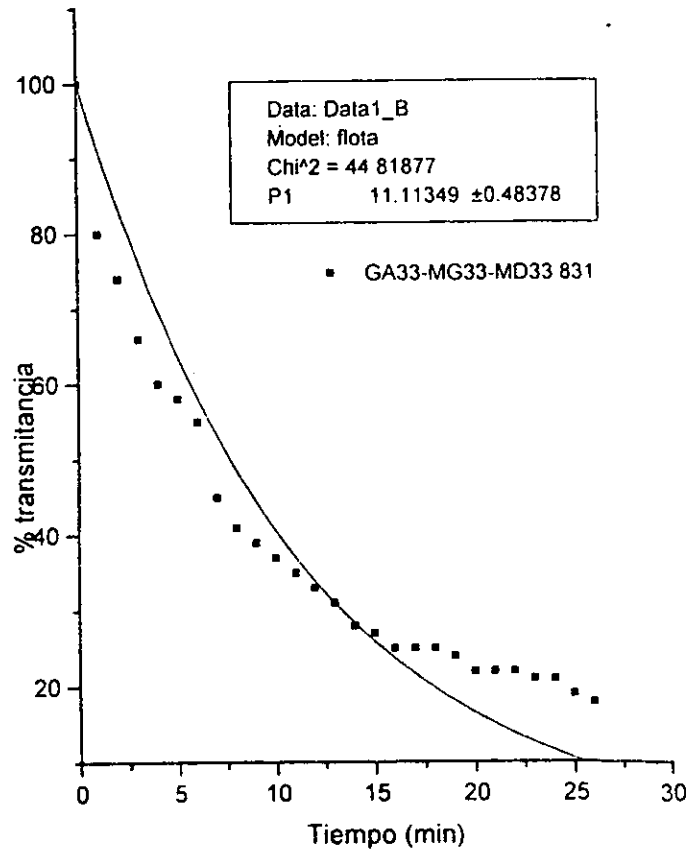
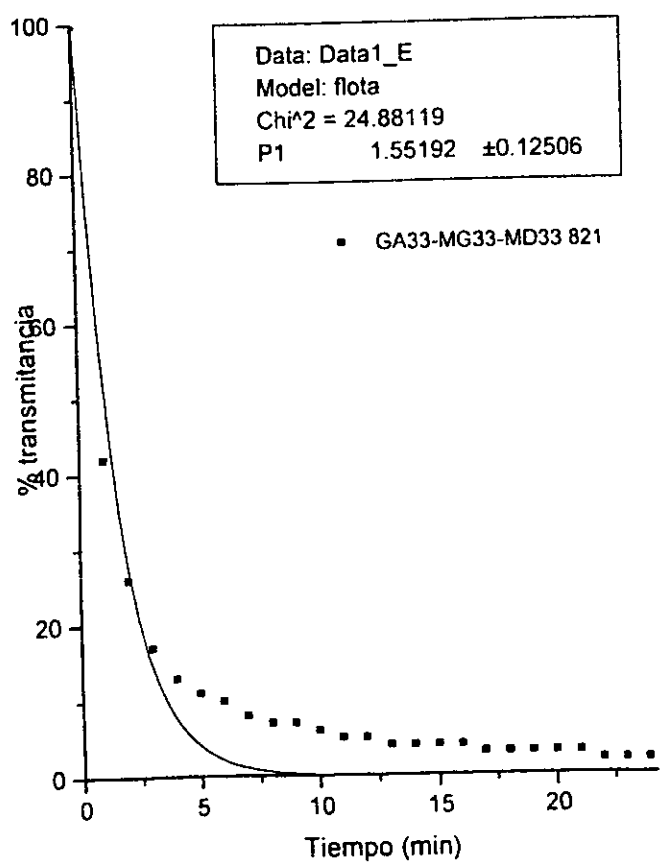
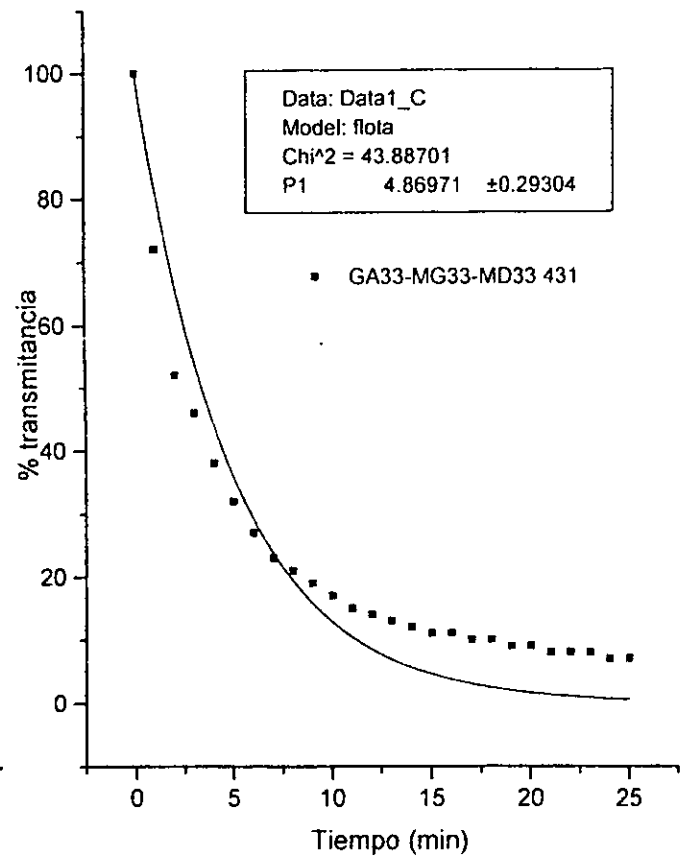
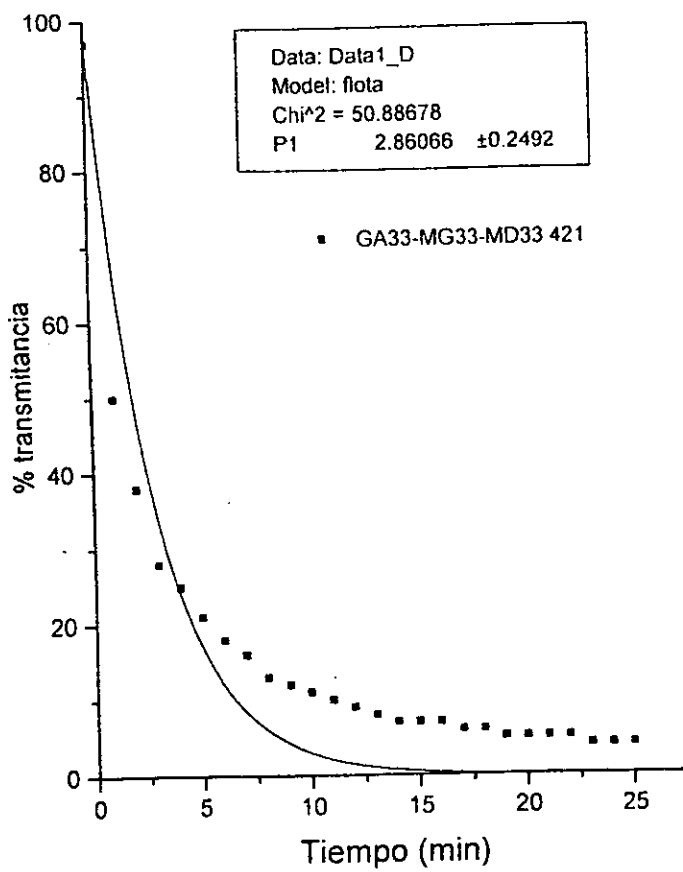


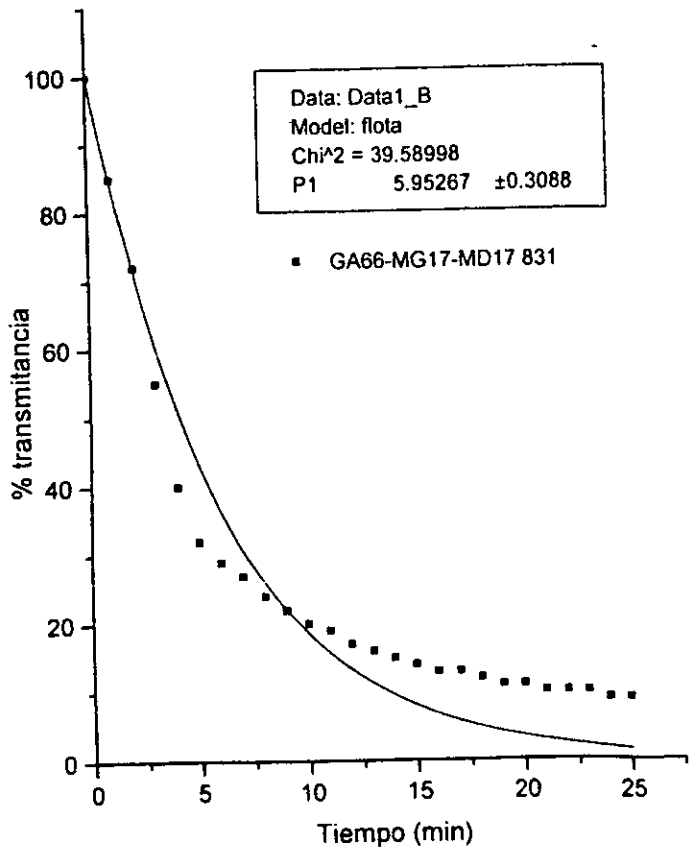
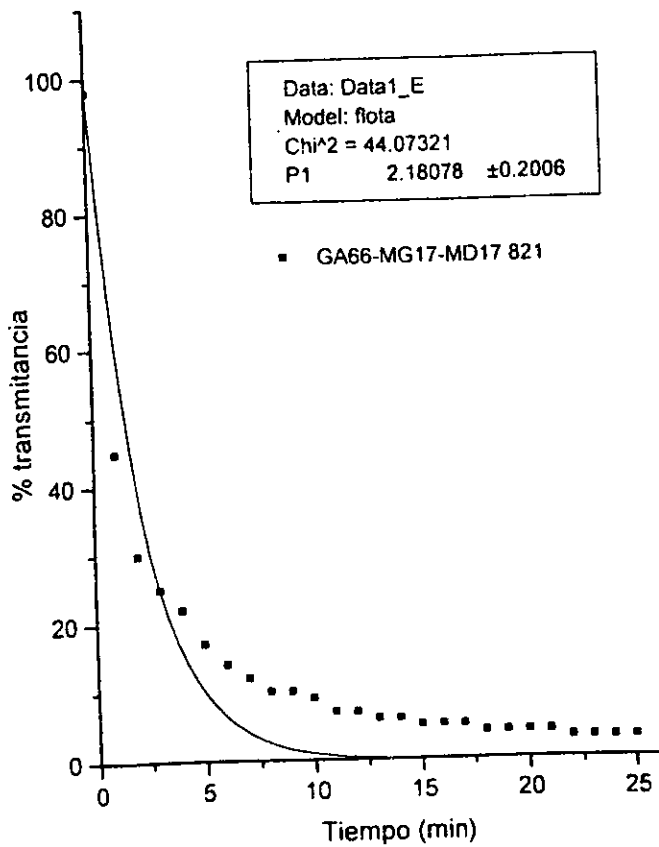
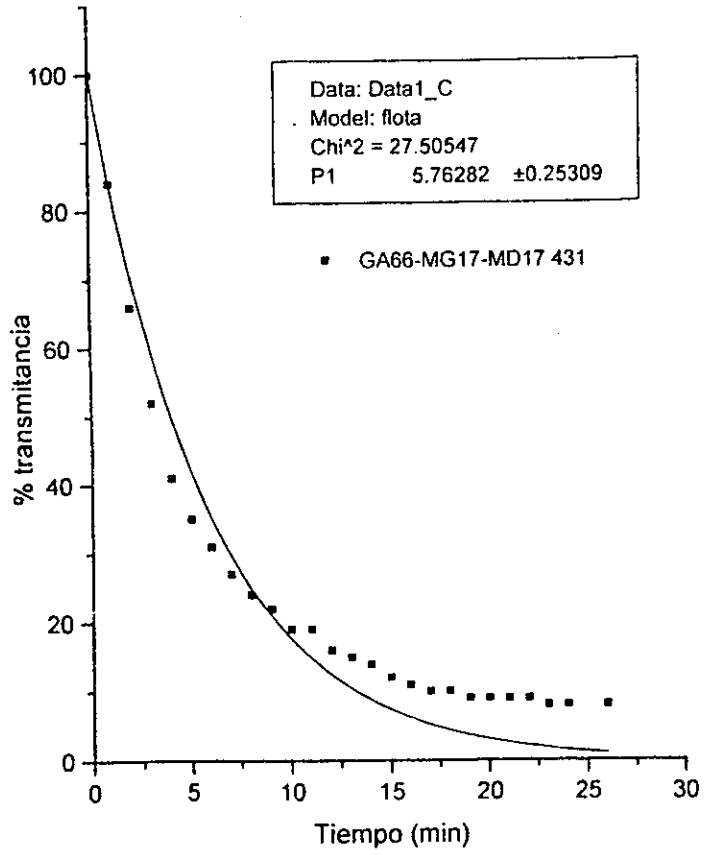
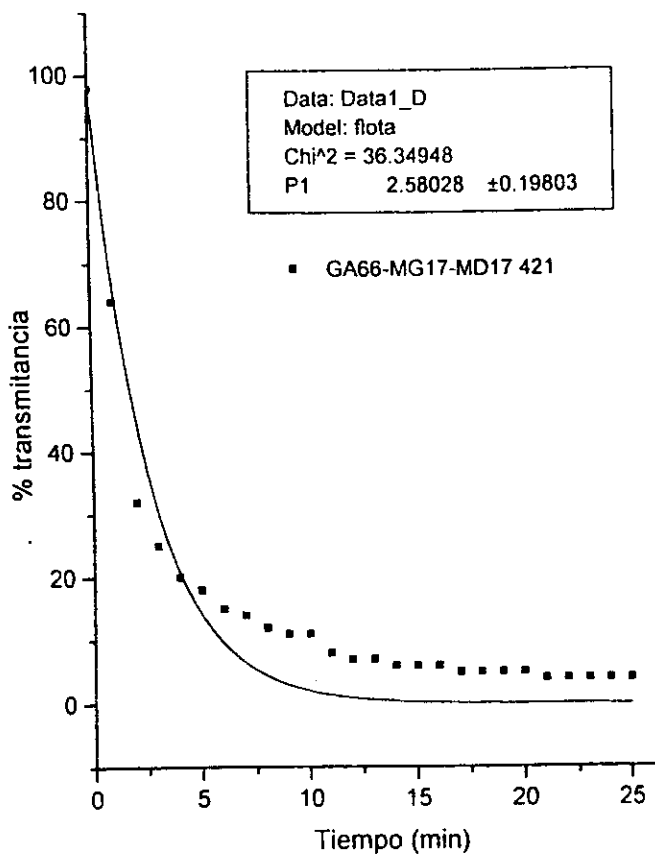


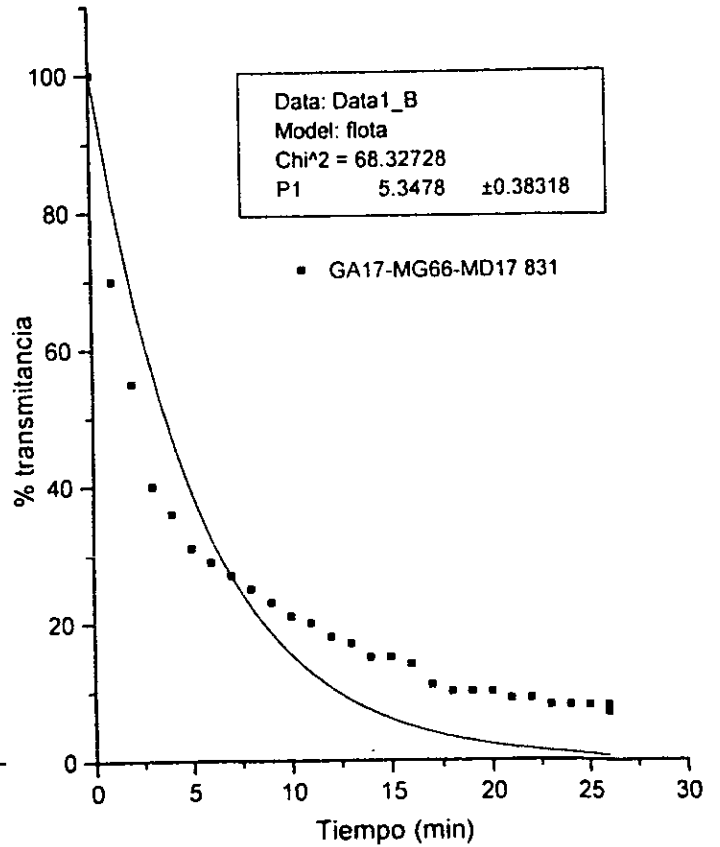
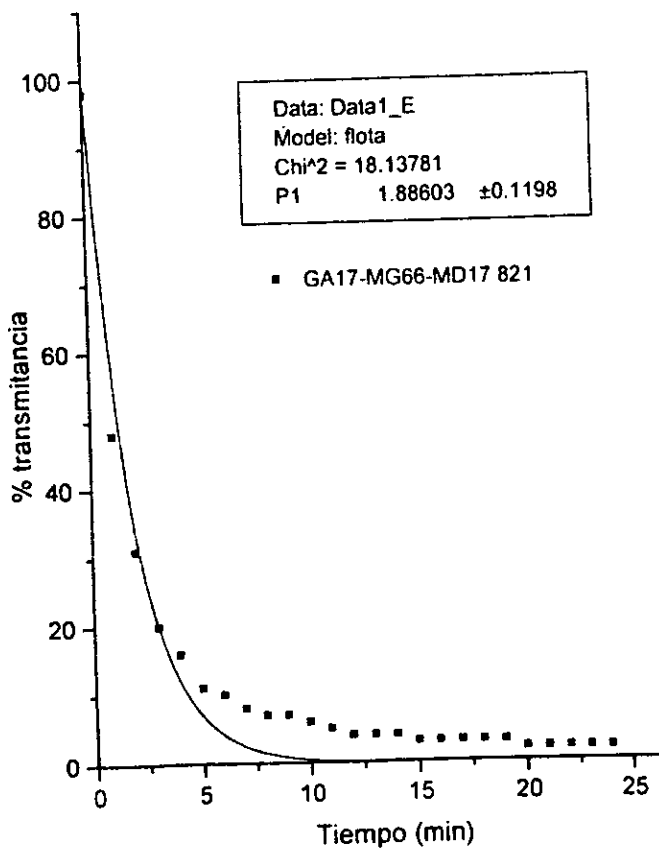
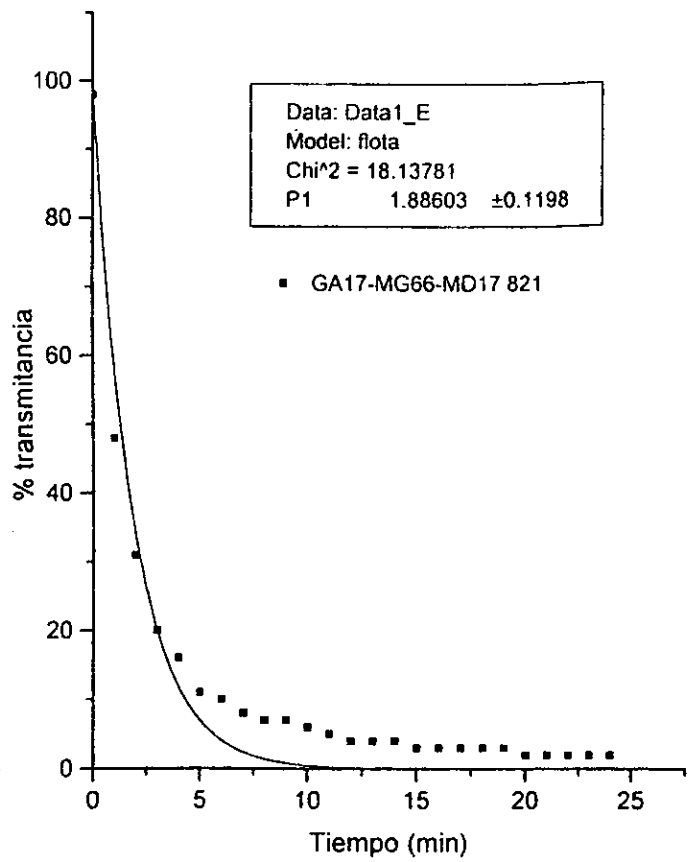
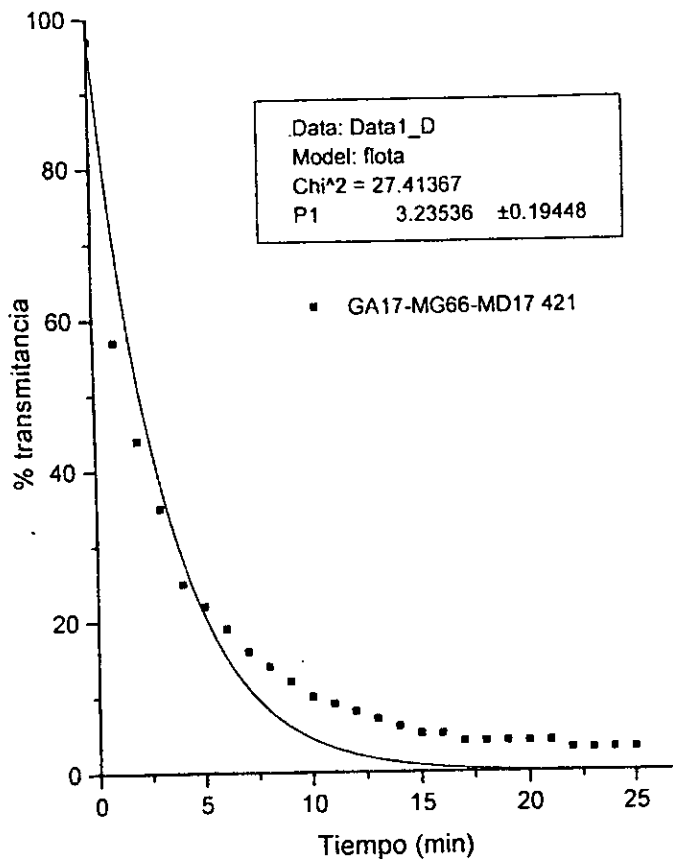




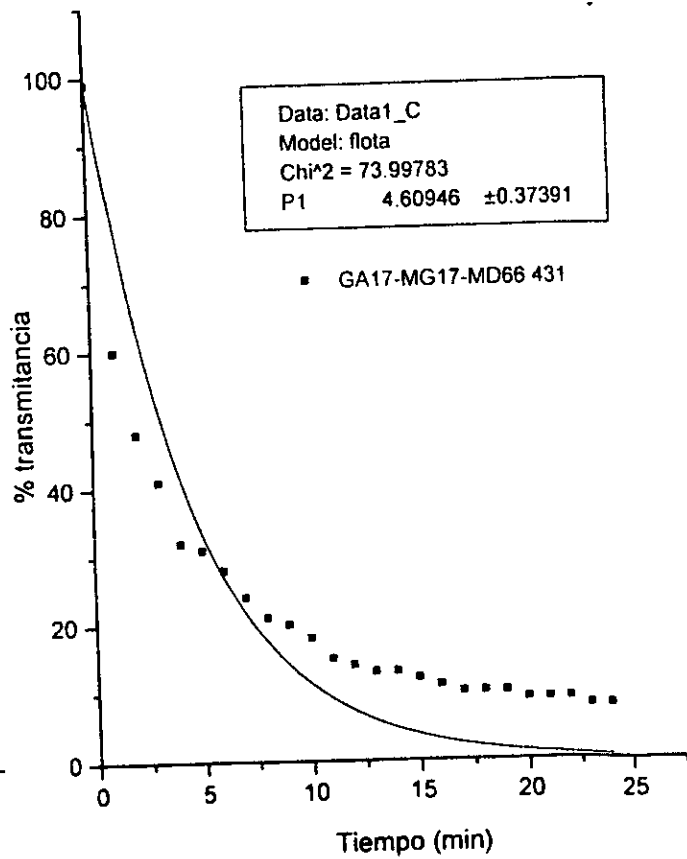
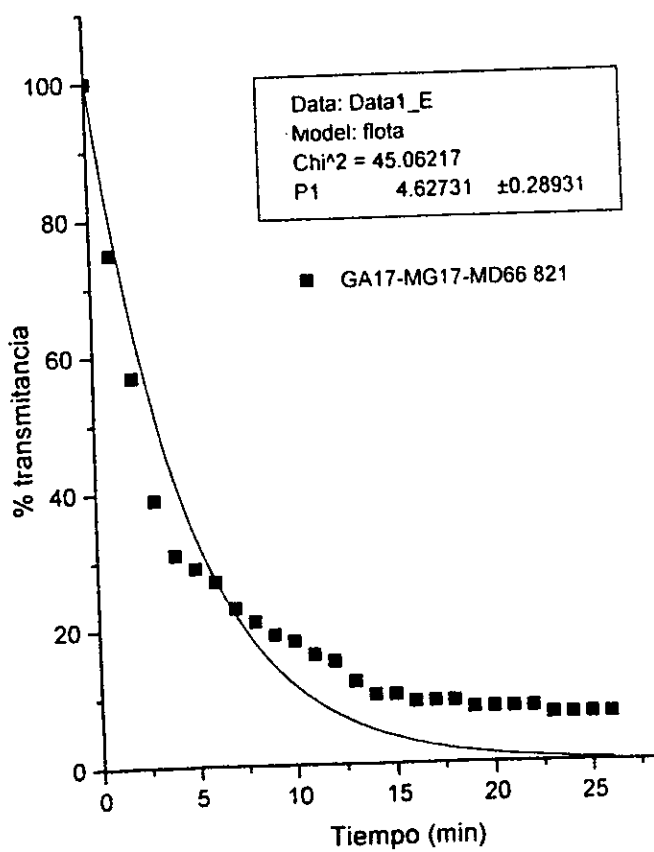
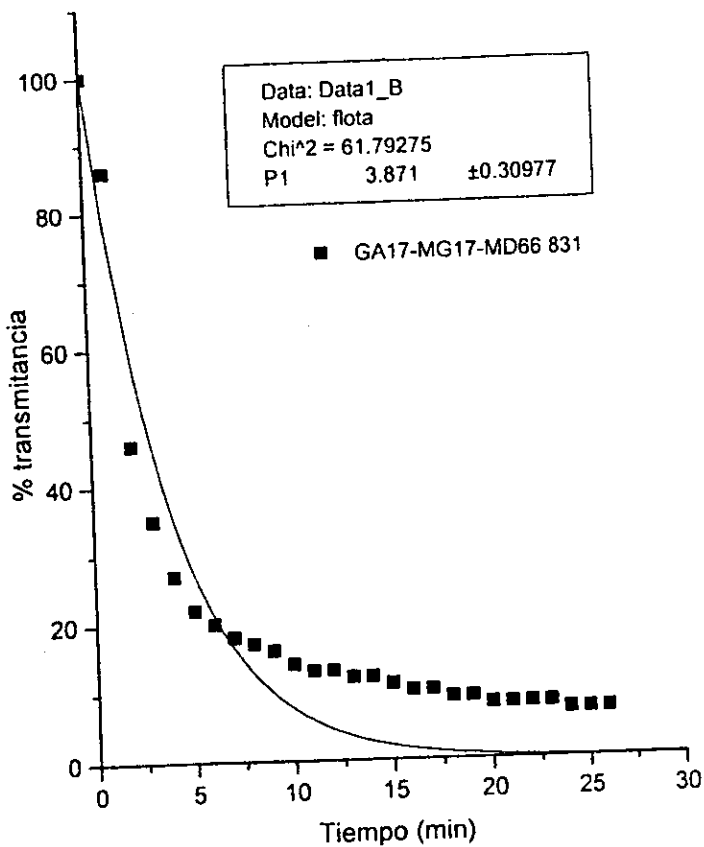
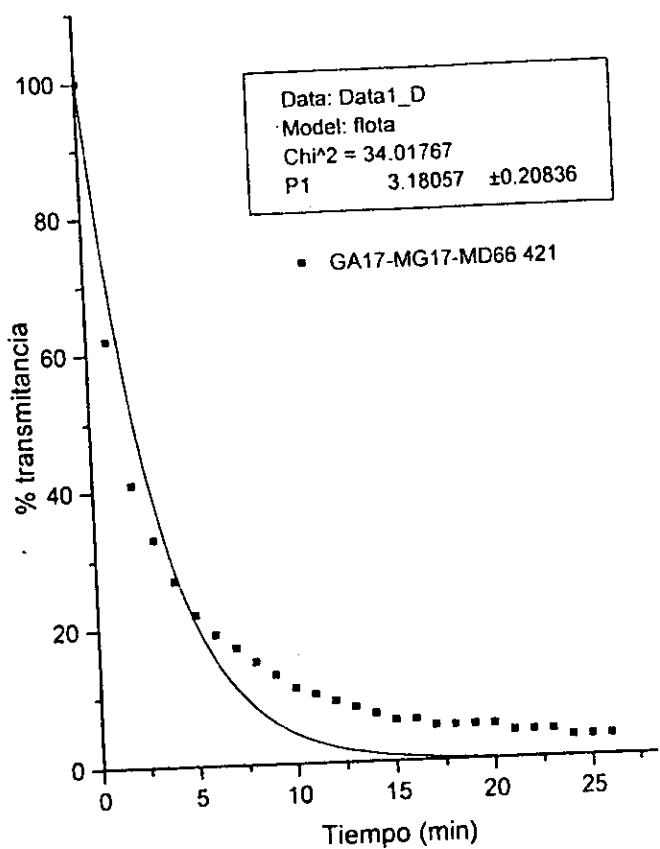












**APÉNDICE 5**  
**Desarrollo matemático para la resolución de la ecuación de difusión**

## Análisis de la transferencia de masa a través de la ecuación de difusión

La ecuación de difusión tiene la forma

$$\frac{\partial \rho}{\partial t} = D \frac{\partial^2 \rho}{\partial y^2}$$

si se desea expresar en peso se tiene que

$$w_i = \frac{\rho_i}{\sum_{i=1}^c \rho_i}$$

como

$$\rho = \sum_{i=1}^c \rho_i$$

por tanto

$$w_i = \frac{\rho_i}{\rho}$$

entonces la ecuación de difusión puede escribirse como

$$\frac{\partial \rho w_i}{\partial t} = D \frac{\partial^2 \rho w_i}{\partial y^2}$$

si  $\rho$  es aproximadamente constante, entonces

$$\frac{\rho \partial w_i}{\partial t} = D \rho \frac{\partial^2 w_i}{\partial y^2}$$

$$\frac{\partial w_i}{\partial t} = D \frac{\partial^2 w_i}{\partial y^2}$$

Se postula que el coeficiente de difusión es una función del peso molecular, ya que tratándose de polímeros, el cambio conformacional de éstos debido a la hidratación, supone cierto grado de interacción entre las cadenas poliméricas lo que tiene como consecuencia que la variación en el coeficiente de difusión esté asociado fuertemente al peso molecular (Ju y cols, 1995a; 1995b)

$$D = aM^b$$

$$D_{(0)} = aM_{(0)}^b$$

$$\lim_{t \rightarrow \infty} D = aM_{\infty}^b$$

En disoluciones poliméricas la distribución de pesos moleculares permite definir la movilidad de las especies. El peso molecular obedece a una relación del tipo:

$$M = (M_0 - M_{\infty})e^{-\beta t} + M_{\infty}$$

La difusividad toma la forma de :

$$D = a \{ (M_0 - M_{\infty})e^{-\beta t} + M_{\infty} \}^b$$

Al sustituir en la ecuación de difusión se establece el modelo siguiente:

$$\frac{\partial w_i}{\partial t} = a \{ (M_0 - M_{\infty})e^{-\beta t} + M_{\infty} \}^b \frac{\partial^2 w_i}{\partial y^2}$$

Como condiciones inicial y de frontera se tienen:

$$\begin{array}{lll} c_i & t = 0 & w_i = 0 \\ c_{F1} & y = R & w_i = w_i^{eq} \\ c_{F2} & y = 0 & \frac{\partial w_i}{\partial y} = 0 \end{array}$$

Se plantean las variables adimensionales siguientes:

$$\theta = \frac{w_i - w_i^{eq}}{w_{i0} - w_i^{eq}}$$

$$\tau = \frac{tD_0}{R^2} = \frac{t}{R^2} aM_0^b$$

donde  $R^2$  equivale a una longitud característica.

$$\zeta = \frac{y}{R}$$

Escribiendo la ecuación de difusión en términos de las variables adimensionales: para la primera derivada con respecto al tiempo y aplicando la regla de la cadena.

$$\frac{\partial w_i}{\partial t} = \frac{\partial w_i}{\partial \theta} \frac{\partial \theta}{\partial \tau} \frac{\partial \tau}{\partial t}$$

$$\frac{\partial w_i}{\partial t} = \frac{(w_{i0} - w_i^{eq}) D_0}{R^2} \frac{\partial \theta}{\partial \tau}$$

Se tiene del modelo establecido que

$$\frac{\partial w_i}{\partial t} = D \frac{\partial^2 w_i}{\partial y^2}$$

$$\frac{\partial w_i}{\partial t} = \frac{(w_{i0} - w_i^{eq})}{R^2} a M_0^b$$

La derivada con respecto a la posición:

$$\frac{\partial w_i}{\partial y} = \frac{\partial w_i}{\partial \theta} \frac{\partial \theta}{\partial \zeta} \frac{\partial \zeta}{\partial y}$$

$$\frac{\partial w_i}{\partial y} = (w_i - w_i^{eq}) \frac{1}{R} \frac{\partial \theta}{\partial \zeta}$$

$$\frac{\partial}{\partial y} \left( \frac{\partial w_i}{\partial y} \right) = \frac{\partial \zeta}{\partial y} \frac{\partial}{\partial \zeta} \left[ (w_i - w_i^{eq}) \frac{1}{R} \frac{\partial \theta}{\partial \zeta} \right]$$

$$\frac{\partial^2 w_i}{\partial y^2} = \frac{(w_{i0} - w_i^{eq})}{R^2} \frac{\partial^2 \theta}{\partial \xi^2}$$

Sustituyendo en el modelo

$$\frac{(w_{i0} - w_i^{eq})}{R^2} a M_0^b \frac{\partial \theta}{\partial \tau} = a [(M_0 - M_\infty) e^{-\beta t} + M_\infty]^b \frac{(w_{i0} - w_i^{eq})}{R^2} \frac{\partial^2 \theta}{\partial \xi^2}$$

rearrreglando y dividiendo entre  $a M_0^b$

$$\frac{\partial \theta}{\partial \tau} = \frac{[(M_0 - M_\infty) e^{-\beta t} + M_\infty]^b}{M_0^b} \frac{\partial^2 \theta}{\partial \xi^2}$$

de la definición de la variable adimensional del tiempo se tiene que

$$t = \frac{\tau R^2}{aM_0^b}$$

así que

$$\frac{\partial \theta}{\partial \tau} = \frac{\left[ (M_0 - M_\infty) e^{-\beta \frac{\tau R^2}{aM_0^b}} + M_\infty \right]^b}{M_0^b} \frac{\partial^2 \theta}{\partial \xi^2}$$

$$\frac{\partial \theta}{\partial \tau} = \left\{ \left( 1 - \frac{M_\infty}{M_0} \right) e^{-\beta \frac{\tau R^2}{aM_0^b}} + \frac{M_\infty}{M_0} \right\}^b \frac{\partial^2 \theta}{\partial \xi^2}$$

de las condiciones de frontera  $\tau = 0, \theta = 1$   
 $\xi = 1, \theta = 0$   
 $\xi = 0, \frac{\partial \theta}{\partial \xi} = 0$

tendremos que el **modelo adimensional** queda descrito por

$$\frac{\partial \theta}{\partial \tau} = f(\tau) \frac{\partial^2 \theta}{\partial \xi^2}$$

donde  $f(\tau)$  se ha definido, para simplificar la expresión, como

$$f(\tau) = \left\{ \left( 1 - \frac{M_\infty}{M_0} \right) e^{-\beta \frac{\tau R^2}{aM_0^b}} + \frac{M_\infty}{M_0} \right\}^b$$

Para la resolución del modelo adimensional se propone el método por separación de variables

$$\theta = ZT = Z(\xi)T(\tau)$$

Se calculan las derivadas respectivas para luego sustituir en la ecuación de difusión:

$$\frac{\partial \theta}{\partial \tau} = \frac{\partial}{\partial \tau} (ZT) = Z \frac{\partial T}{\partial \tau}$$

$$\frac{\partial^2 \theta}{\partial \xi^2} = \frac{\partial}{\partial \xi} \left( \frac{\partial \theta}{\partial \xi} \right) = \frac{\partial}{\partial \xi} \left( \frac{\partial(ZT)}{\partial \xi} \right)$$

$$\frac{\partial^2 \theta}{\partial \xi^2} = T \frac{\partial^2 \theta}{\partial \xi^2}$$

entonces

$$Z \frac{\partial T}{\partial \tau} = f(\tau) T \frac{\partial^2 Z}{\partial \xi^2}$$

dividiendo ambos lados de la ecuación entre  $f(\tau) \frac{T}{Z}$

$$\frac{1}{f(\tau) T} \frac{\partial T}{\partial \tau} = \frac{1}{Z} \frac{\partial^2 Z}{\partial \xi^2}$$

Como la dependencia es de una variable, las derivadas parciales pueden escribirse como ordinarias

$$\frac{1}{f(\tau) T} \frac{dT}{d\tau} = \frac{1}{Z} \frac{d^2 Z}{d\xi^2}$$

Al tratarse de dos funciones con diferente variable, pero iguales entre sí, entonces es igual a una constante

$$\frac{1}{f(\tau) T} \frac{dT}{d\tau} = \frac{1}{Z} \frac{d^2 Z}{d\xi^2} = -\lambda^2$$

$$\frac{1}{f(\tau) T} \frac{dT}{d\tau} = -\lambda^2$$

$$\frac{dT}{d\tau} + \lambda^2 f(\tau) T = 0$$

ésta es una ecuación del tipo

$$\frac{dy}{dx} + P(x)y = Q(x)$$

para resolverla se utiliza un factor de integración de la forma:

$$\frac{d}{dx} \left[ e^{\int P(x) dx} y \right] = Q(x) e^{\int P(x) dx}$$

Se tiene entonces que

$$\frac{dT}{d\tau} = -\lambda^2 f(\tau) T$$

$$\int \frac{dT}{T} = -\lambda^2 \int f(\tau) d\tau$$

$$\ln T = -\lambda^2 \int f(\tau) d\tau + \ln c$$

$$\ln \frac{T}{c} = -\lambda^2 \int f(\tau) d\tau$$

por lo tanto

$$T = ce^{-\lambda^2 \int f(\tau) d\tau}$$

Ahora

$$\frac{1}{Z} \frac{d^2 Z}{d\xi^2} = -\lambda^2$$

$$\frac{d^2 Z}{d\xi^2} + \lambda^2 Z = 0$$

$$Z = c_1 e^{i\lambda\xi} + c_2 e^{-i\lambda\xi}$$

$$Z = c_1 \cos \lambda\xi + c_2 \operatorname{sen} \lambda\xi$$

Sustituyendo la condición inicial de frontera,  $\theta = 0, \xi = 1$  (para toda  $\tau$ ), en la solución anterior se tiene

$$Z = c_1 \cos \lambda(1) + c_2 \operatorname{sen} \lambda(1) = 0$$



Aplicando la segunda condición de frontera  $\xi = 0$ ,  $\frac{\partial \theta}{\partial \xi} = 0$ ,  $\frac{\partial Z}{\partial \xi} = 0$

$$\frac{\partial Z}{\partial \xi} = -c_1 \lambda \operatorname{sen} \lambda \xi + c_2 \lambda \cos \lambda \xi$$

$$-c_1 \lambda \operatorname{sen} \lambda \xi + c_2 \lambda \cos \lambda \xi = 0$$

$$-c_1 \lambda \operatorname{sen} \lambda(0) + c_2 \lambda \cos \lambda(0) = 0$$

$$c_2 \lambda = 0$$

$$c_2 = 0$$

Sustituyendo el valor de  $c_2 = 0$  en la ecuación de  $Z$

$$c_1 \cos \lambda = 0$$

pero cuando

$$\cos \lambda = 0$$

se cumple para todos los valores de  $\lambda = (2n + 1) \frac{\pi}{2}$ , entonces la solución de  $Z$  sería

$$Z_n = c_n \cos \left[ (2n + 1) \frac{\pi}{2} \xi \right]$$

Se tendrían una gran serie de soluciones, por el principio de superposición, la suma de todas las soluciones es también una solución de la ecuación, así que

$$Z = \sum_{n=0}^{\infty} c_n \cos \left[ (2n + 1) \frac{\pi}{2} \xi \right]$$

Anteriormente se tenía que

$$\theta = TZ$$

$$\theta = \sum_{n=0}^{\infty} c_n \cos \left[ (2n + 1) \frac{\pi}{2} \xi \right] c e^{-\lambda^2 \int f(\tau) d\tau}$$

Definiendo una  $A_n = c_n c$  podemos escribir que

$$\theta = \sum_{n=0}^{\infty} A_n \cos \left[ (2n+1) \frac{\pi}{2} \xi \right] e^{-\lambda^2 \int f(\tau) d\tau}$$

Ahora faltaría por evaluar el valor de las constantes.

De la condición de frontera  $\tau = 0, \theta = 1$ , al sustituir se tiene

$$1 = \sum_{n=0}^{\infty} A_n \cos (2n+1) \frac{\pi}{2} \xi$$

por el principio de ortogonalidad de la función cos, se procede a evaluar el valor de las constantes:

$$\sum_{n=0}^{\infty} A_n \left[ \cos (2n+1) \frac{\pi}{2} \xi \right] \cos \left[ (2m+1) \frac{\pi}{2} \xi \right] = \cos \left[ \cos (2m+1) \frac{\pi}{2} \xi \right]$$

si se integran ambos lados de la ecuación, comenzando con el término del lado izquierdo se tiene

$$\sum_{n=0}^{\infty} A_n \int \cos \left[ (2n+1) \frac{\pi}{2} \xi \right] \cos \left[ (2m+1) \frac{\pi}{2} \xi \right] d\xi$$

desarrollando la serie y considerando que  $\int \cos n\xi \cos m \xi d\xi \begin{cases} 0 & \text{si } n \neq m \\ 1/2 & \text{si } n = m \end{cases}$

$$A_n \int_0^1 \cos^2 \left[ \frac{(2n+1)}{2} \pi \xi \right] d\xi$$

$$A_n \left\{ \int_0^1 \frac{1}{2} d\xi + \frac{1}{2} \int_0^1 \cos \left[ (2n+1) \frac{\pi}{2} \xi \right] d\xi \right\}$$

integrando se tiene

$$A_n \left\{ \frac{1}{2} \xi + \frac{1}{2(2n+1)\pi} \operatorname{sen} (2n+1) \pi \xi \right\}_0^1$$

la expresión anterior corresponde al lado izquierdo de la ecuación:

La integral del lado derecho sería

$$\int_0^1 \cos \left[ \frac{(2n+1)}{2} \pi \xi \right] d\xi - \frac{2}{(2n+1)\pi} \operatorname{sen} \frac{(2n+1)}{2} \pi$$

igualando el lado izquierdo con el derecho y despejando  $An$  se tiene

$$An = \frac{\frac{2}{(2n+1)\pi} \operatorname{sen} \left[ \frac{(2n+1)}{2} \pi \right]}{\frac{1}{2} + \frac{\operatorname{sen}}{2(2n+1)\pi} [(2n+1)\pi]}$$

$$An = \frac{\frac{2}{2(2n+1)\pi} \operatorname{sen} \left[ \frac{(2n+1)}{2} \pi \right]}{\frac{(2n+1)\pi}{2(2n+1)\pi} + \frac{\operatorname{sen}(2n+1)\pi}{2(2n+1)\pi}}$$

$$An = \frac{4 \operatorname{sen} \left[ \frac{(2n+1)\pi}{2} \right]}{(2n+1)\pi + \operatorname{sen} [(2n+1)\pi]}$$

como  $\operatorname{sen}(2n+1) = 0$

$$An = \frac{4 \operatorname{sen} \left[ \frac{(2n+1)\pi}{2} \right]}{(2n+1)\pi}$$

Entonces, la solución es

$$\theta = \sum_{n=0}^{\infty} \frac{4 \operatorname{sen} \left[ \frac{(2n+1)\pi}{2} \right]}{(2n+1)\pi} \cos \left[ \frac{(2n+1)}{2} \pi \xi \right] e^{-\left[ \frac{(2n+1)}{2} \pi \right]^2 \int_0^{\tau} f(\tau) d\tau}$$

donde

$$f(\tau) = \left\{ \left( 1 - \frac{M_{\infty}}{M_0} \right) e^{-\beta \frac{R^2}{\alpha M_0^b} \tau} + \frac{M_{\infty}}{M_0} \right\}^b$$

para valores de  $\tau$  y considerando que  $\tau = \frac{t \alpha M_0^b}{R^2}$

Ahora se va a tomar sólo el primer término de la serie, esto es  $n=0$

$$\theta = \frac{4 \operatorname{sen} \frac{\pi}{2}}{\pi} \cos \left[ \frac{\pi}{2} \xi \right] e^{-\left( \frac{\pi}{2} \right)^2 \int_0^{\tau} f(\tau) d\tau}$$

como  $\operatorname{sen} \frac{\pi}{2} = 1$ , entonces tenemos la función solución de la ecuación de difusión, la cual describe un perfil adimensional de la fracción masa

$$\theta = \frac{4}{\pi} \cos \left( \frac{\pi}{2} \xi \right) e^{-\left( \frac{\pi}{2} \right)^2 \int_0^{\tau} f(\tau) d\tau}$$

Para el cálculo del flux del agente activo:

$$J_d|_{y=R} = -D \frac{\partial w_d}{\partial y} \Big|_{y=R}$$

como  $\frac{\partial w_d}{\partial y} = \frac{w_{i0} - w_i^{eq}}{R} \frac{\partial \theta}{\partial \xi}$  entonces se puede escribir

$$J_d = -D \frac{w_{i0} - w_i^{eq}}{R} \frac{\partial \theta}{\partial \xi} \Big|_{\xi=1}$$

derivando  $\theta$

$$\frac{\partial \theta}{\partial \xi} \Big|_{\xi=1} = -2 \operatorname{sen}^2\left(\frac{\pi}{2}\right) e^{-\left(\frac{\pi}{2}\right)^2 \int_0^\tau f(\tau) d\tau}$$

como  $\operatorname{sen}\frac{\pi}{2} = 1$

$$\frac{\partial \theta}{\partial \xi} \Big|_{\xi=1} = -2 e^{-\left(\frac{\pi}{2}\right)^2 \int_0^\tau f(\tau) d\tau}$$

sustituyendo en la ecuación del flux, tendríamos la expresión total del flux

$$J_d = 2D \frac{(w_{i0} - w_i^{eq})}{R} e^{-\left(\frac{\pi}{2}\right)^2 \int_0^\tau f(\tau) d\tau}$$

Ahora, para calcular la disolución por partícula se tiene

$$\mathfrak{D}(t) = \int_0^t \int_0^A J_d dA_p dt$$

$$\mathfrak{D}(t) = A_p \int_0^t J_d dt$$

$$\mathfrak{D}(t) = 4\pi R^2 \int_0^t \left\{ 2D \left( \frac{w_{d0} - w_d^{eq}}{R} \right) e^{-\left(\frac{\pi}{2}\right)^2 \int_0^\tau f(\tau) d\tau} \right\} dt$$

$$\mathfrak{D}(t) = 8\pi R^2 (w_{d0} - w_d^{eq}) \int_0^t \left\{ \left[ (M_0 - M_\infty) e^{-\beta \frac{R^2}{aM_0^b} \tau} + \frac{M_\infty}{M_0} \right]^b e^{-\left(\frac{\pi}{2}\right)^2 \int_0^\tau f(\tau) d\tau} \right\} dt$$

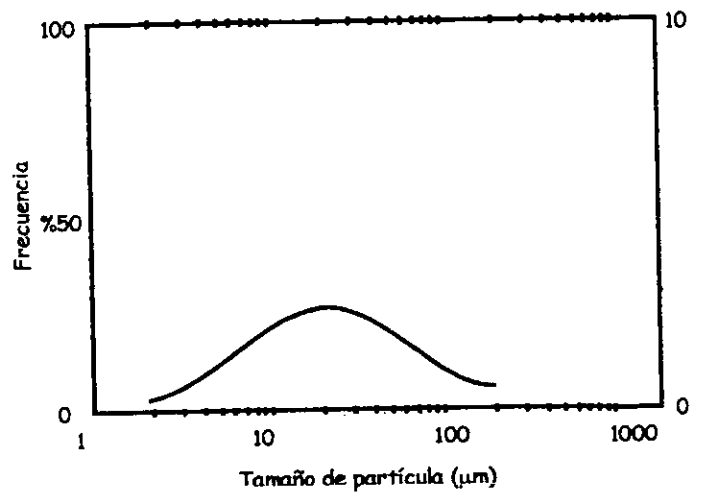
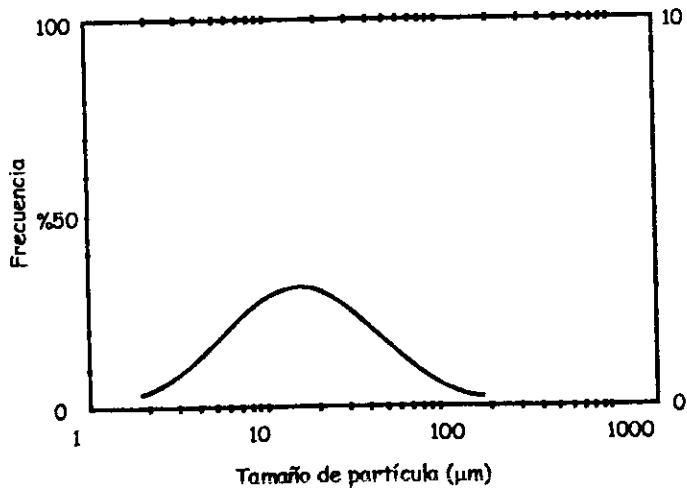
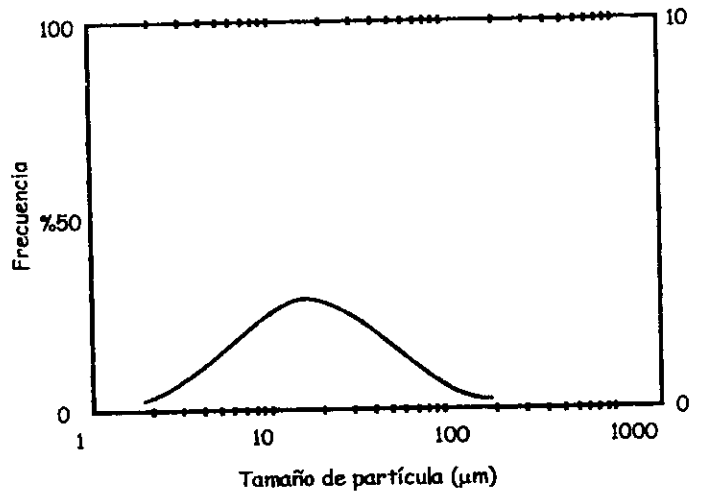
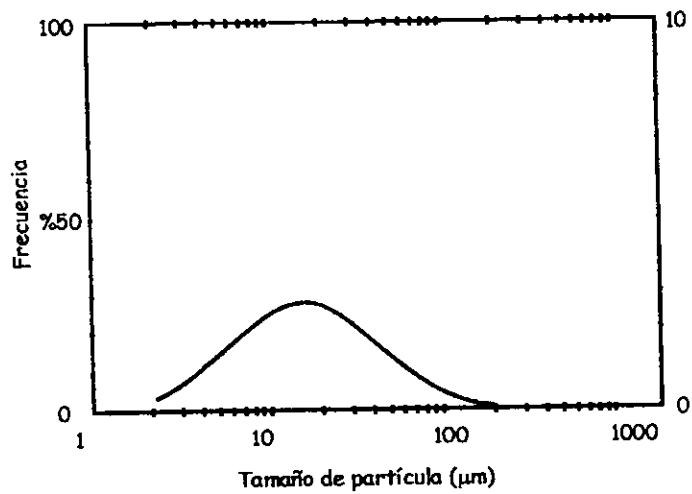
como  $t = \frac{R^2}{aM_0^b} \tau$ ,  $dt = \frac{R^2}{aM_0^b} d\tau$  entonces podemos cambiar la ecuación en función de  $\tau$  y cambiar también los límites entre 0 y  $\tau$  lo que genera la expresión que permite saber la disolución por partícula

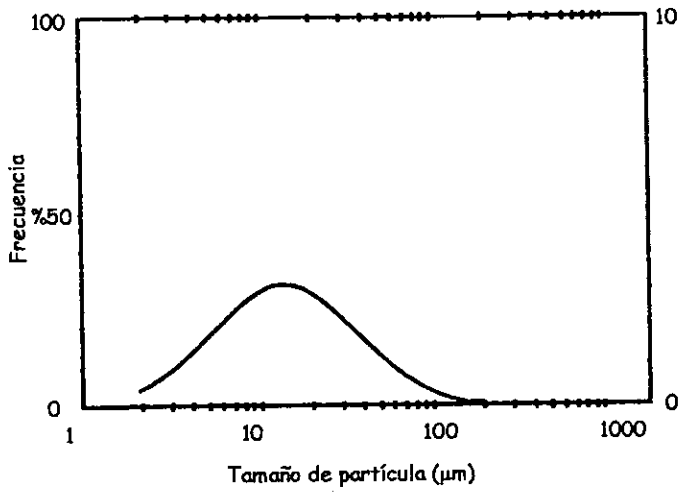
$$\mathfrak{D}(t) = 8\pi R^2 (w_{d0} - w_d^{eq}) \int_0^\tau \left\{ \left[ \frac{(M_0 - M_\infty) e^{-\beta \frac{R^2}{aM_0^b} \tau} + \frac{M_\infty}{M_0}}{aM_0^b} \right]^b e^{-\left(\frac{\pi}{2}\right)^2 \int_0^\tau f(\tau) d\tau} \right\} d\tau$$

La disolución total  $\mathfrak{D}_T$  va a estar dada por

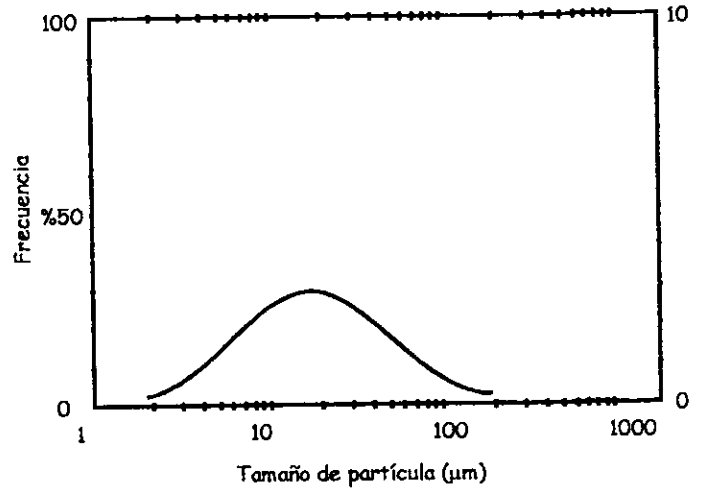
$$\mathfrak{D}_T = n_p V 8\pi R (w_{d0} - w_d^{eq}) \int_0^t \left\{ \left[ (M_0 - M_\infty) e^{-\beta \frac{R^2}{aM_0^2} \tau} + \frac{M_\infty}{M_0} \right]^b e^{-\left(\frac{\pi}{2}\right)^2 \int_0^\tau f(\tau) d\tau} \right\} dt$$

**APÉNDICE 6**  
**Distribución de tamaño de partícula de los tratamientos**

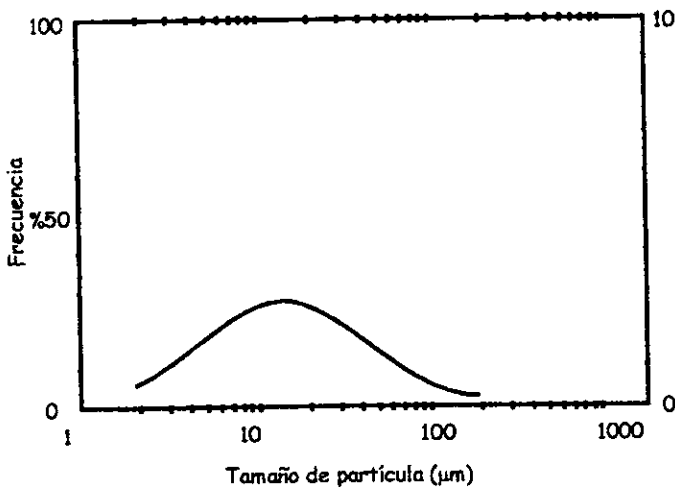




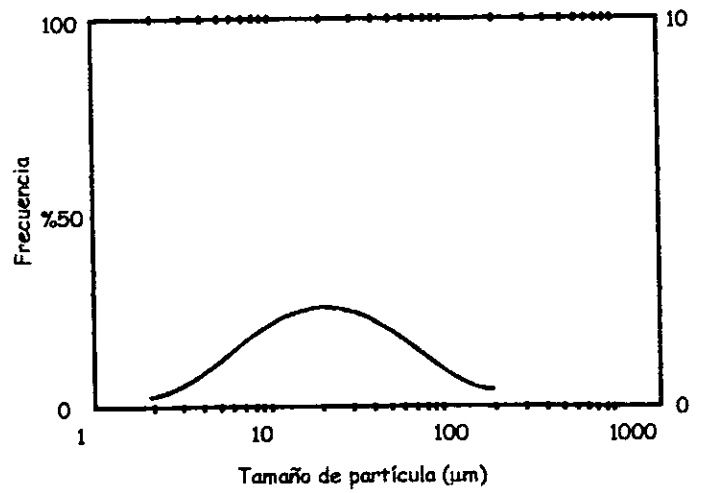
**GM100 E-421**  
**Media volumétrica 19.53 µm**



**GM100 E-431**  
**Media volumétrica 26.04 µm**

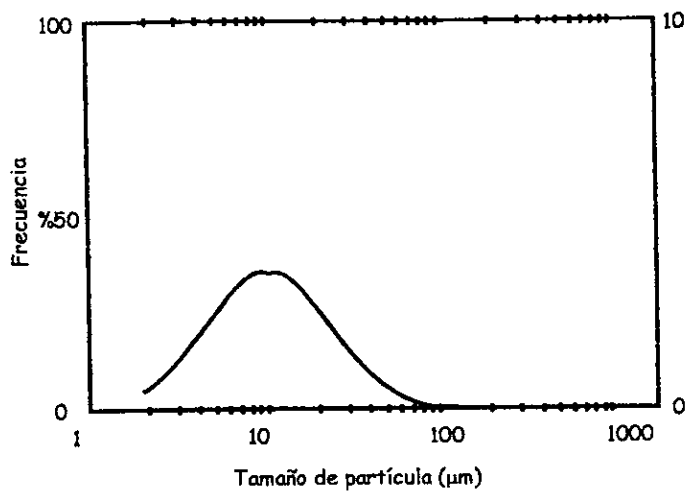


**GM100 E-821**  
**Media volumétrica 22.50 µm**

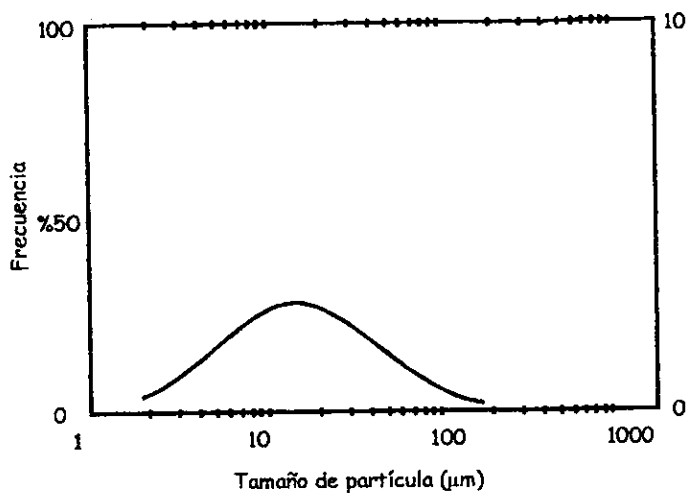


**GM100 E-831**  
**Media volumétrica 31.44 µm**

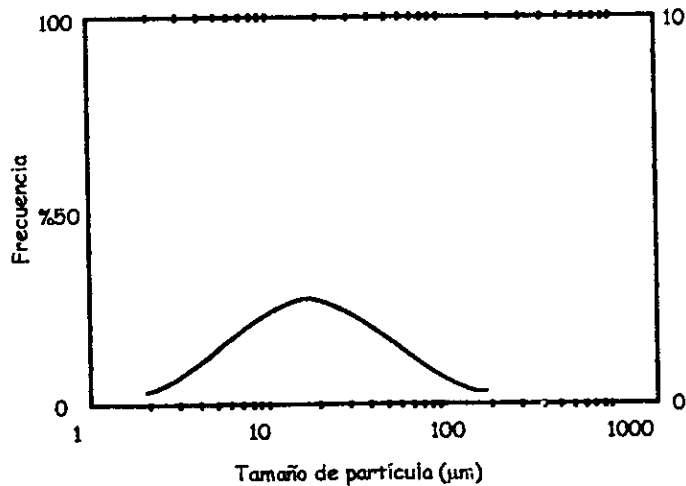




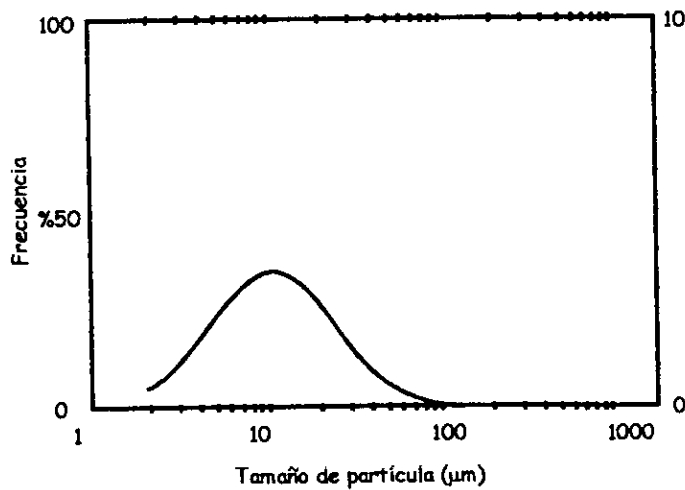
**MD100 E-421**  
**Media volumétrica 13.88 µm**



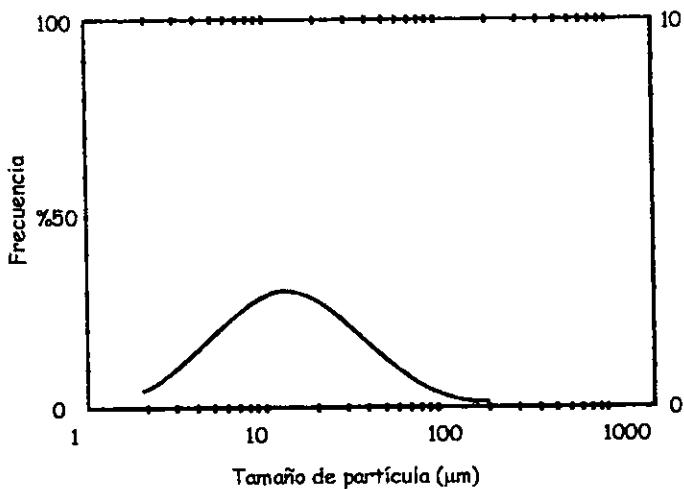
**MD100 E-431**  
**Media volumétrica 24.39 µm**



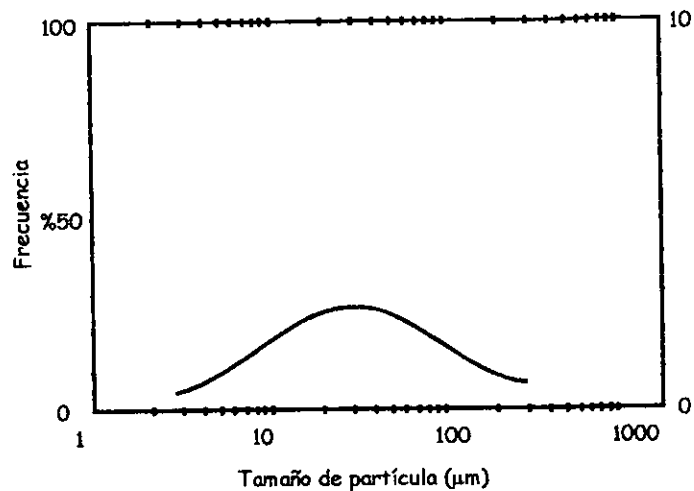
**MD100 E-821**  
**Media volumétrica 26.14 µm**



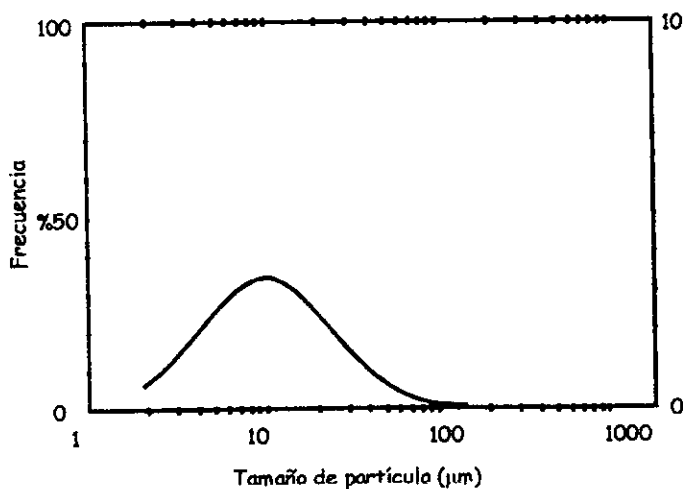
**MD100 E-831**  
**Media volumétrica 13.82 µm**



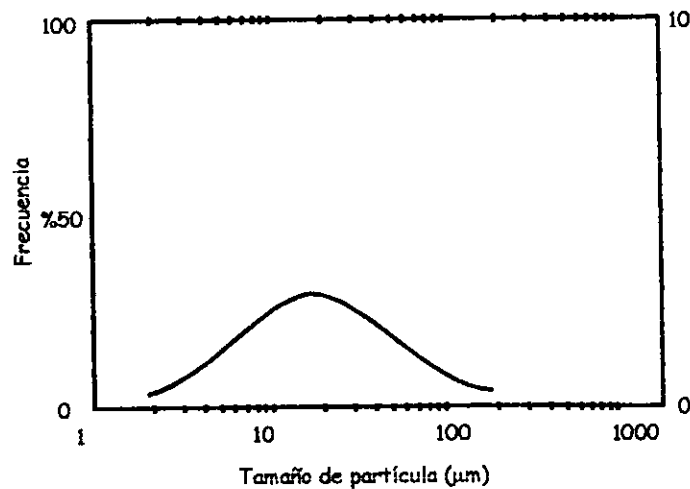
**GA50-GM50 E-421**  
**Media volumétrica 19.30 µm**



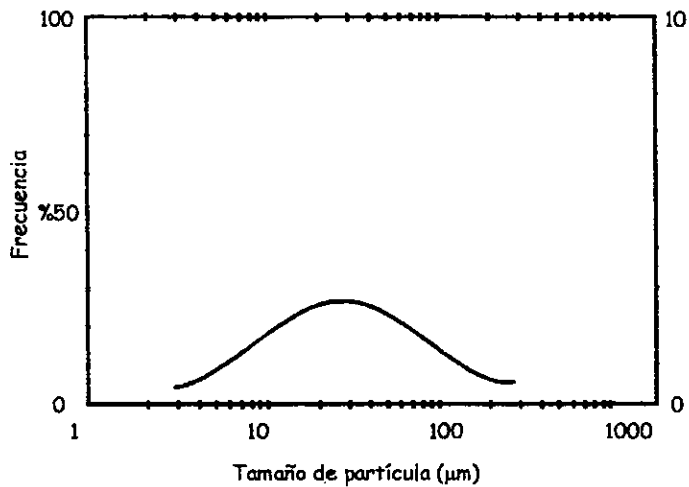
**GA50-GM50 E-431**  
**Media volumétrica 31.28 µm**



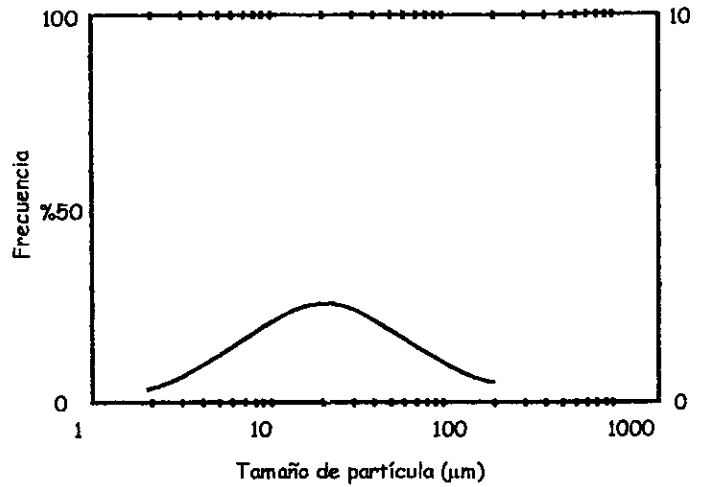
**GA50-GM50 E-821**  
**Media volumétrica 13.80 µm**



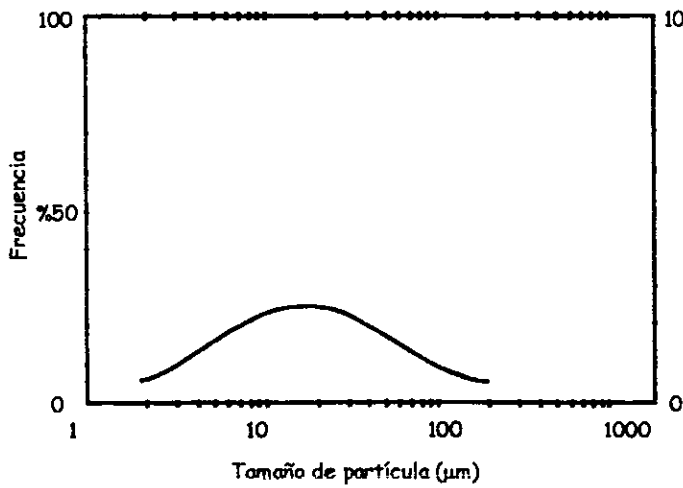
**GA50-GM50 E-831**  
**Media volumétrica 27.25 µm**



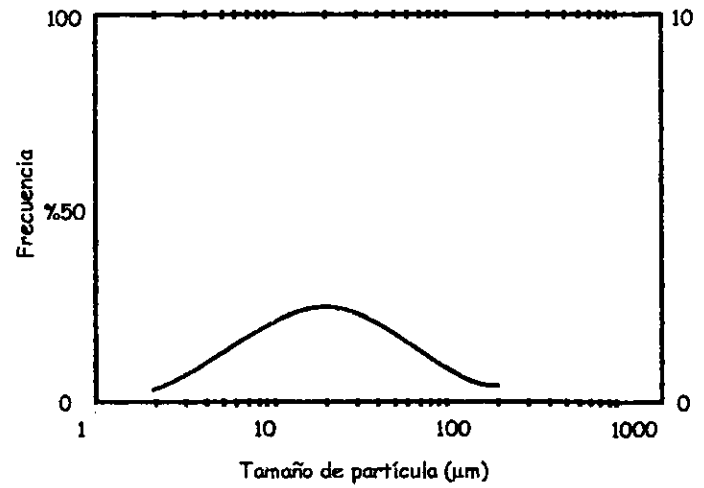
**GA50-MD50 E-421**  
**Media volumétrica 28.58 µm**



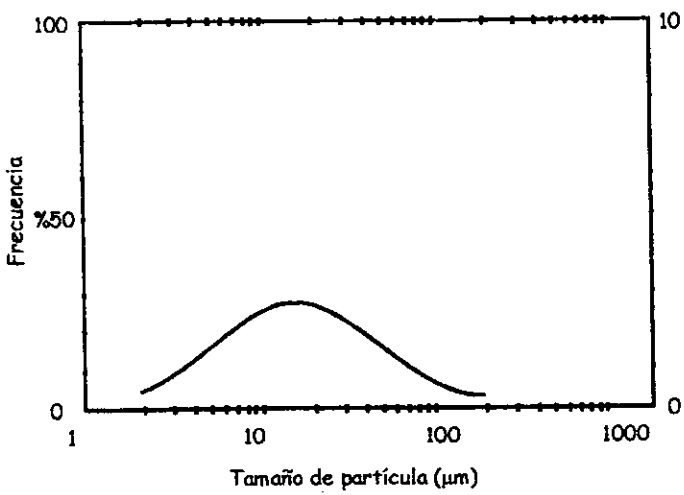
**GA50-MD50 E-431**  
**Media volumétrica 31.28 µm**



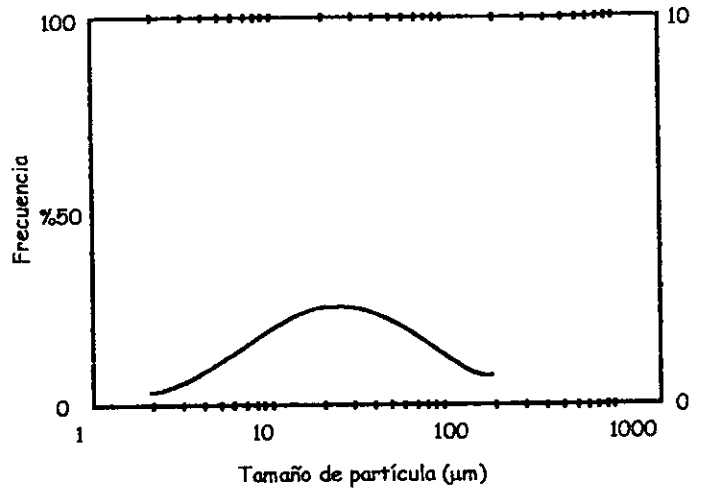
**GA50-MD50 E-821**  
**Media volumétrica 27.20 µm**



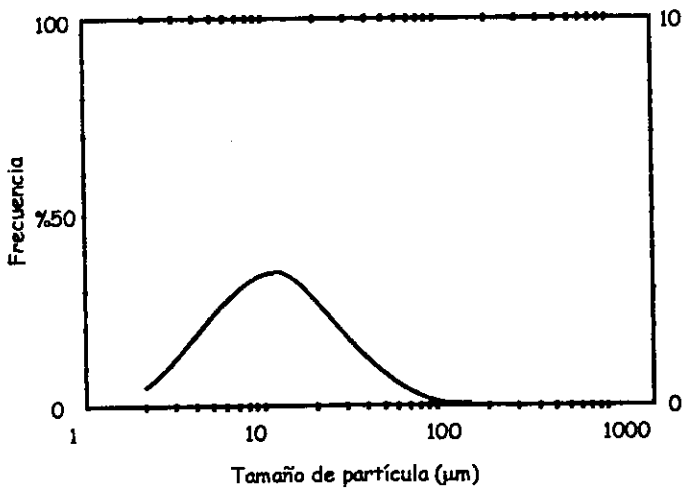
**GA50-MD50 E-831**  
**Media volumétrica 25.51 µm**



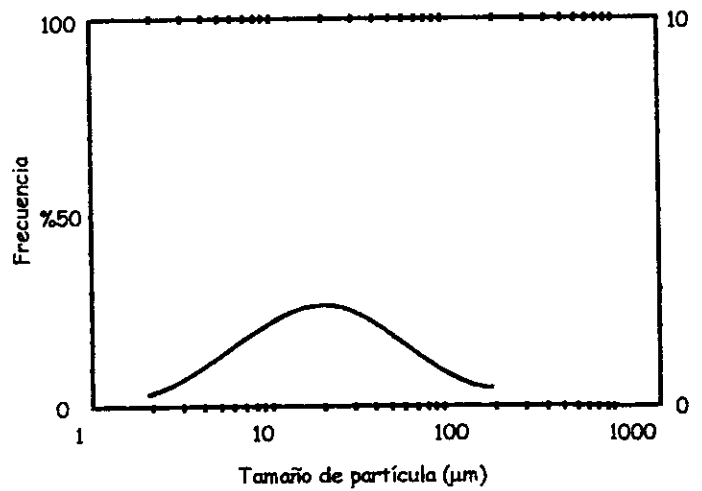
**GM50-MD50 E-421**  
**Media volumétrica 24.61 µm**



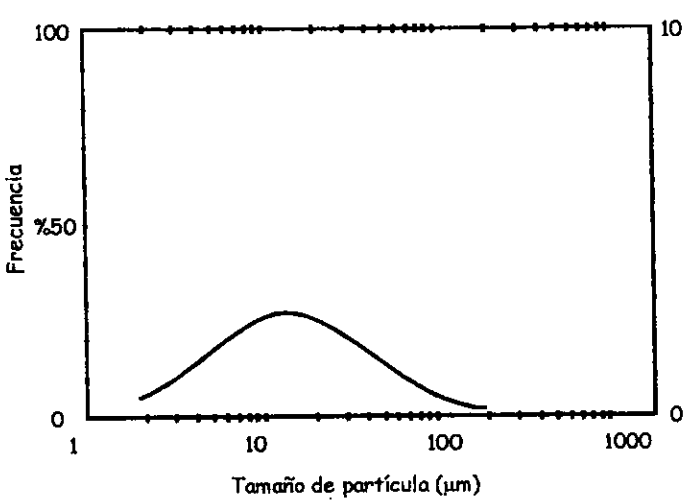
**GM50-MD50 E-431**  
**Media volumétrica 34.42 µm**



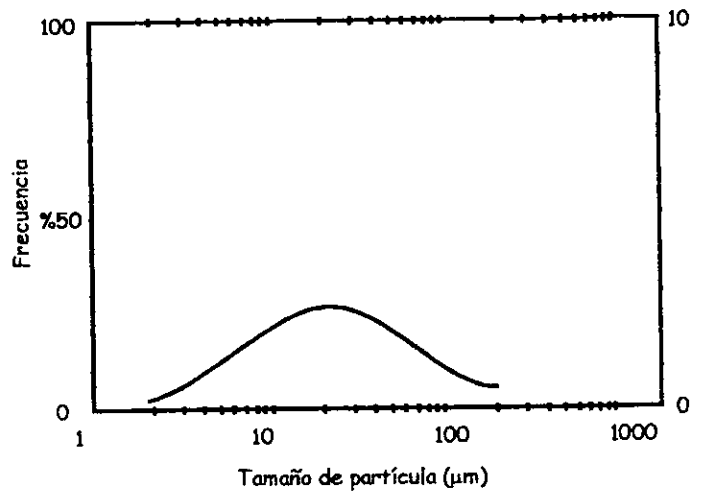
**GM50-MD50 E-821**  
**Media volumétrica 13.80 µm**



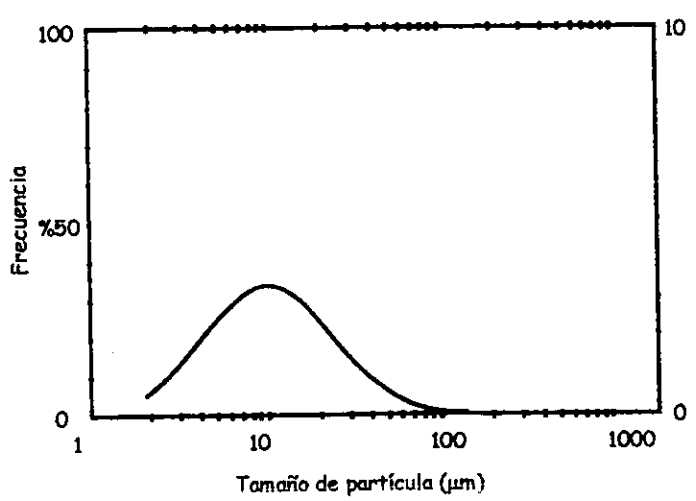
**GM50-MD50 E-831**  
**Media volumétrica 30.04 µm**



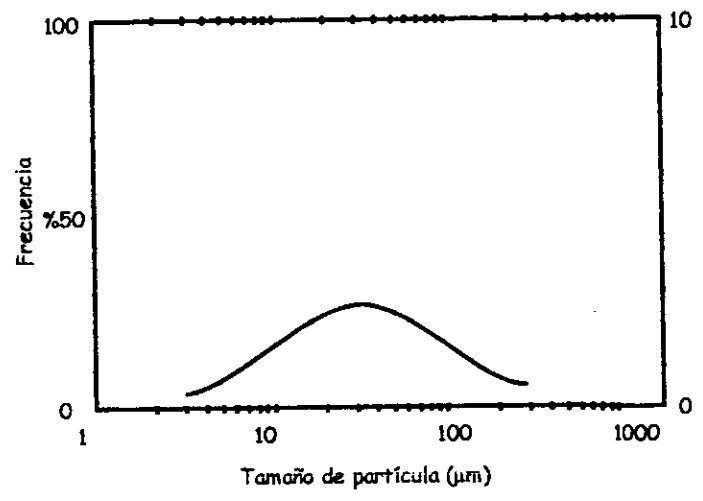
**GA33-GM33-MD33 E-421**  
**Media volumétrica 22.5 µm**



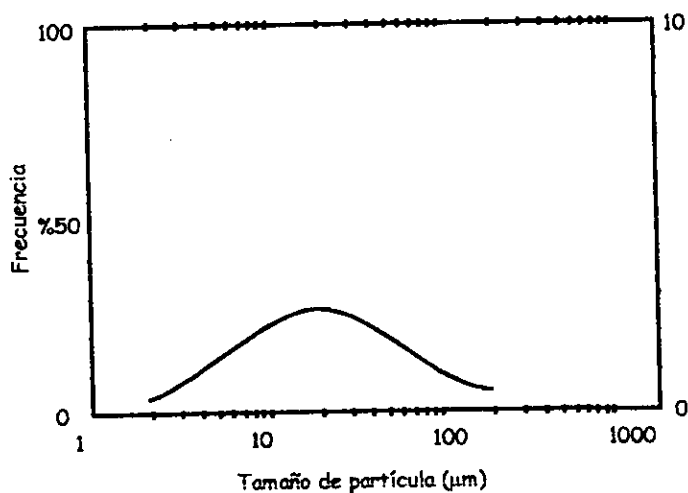
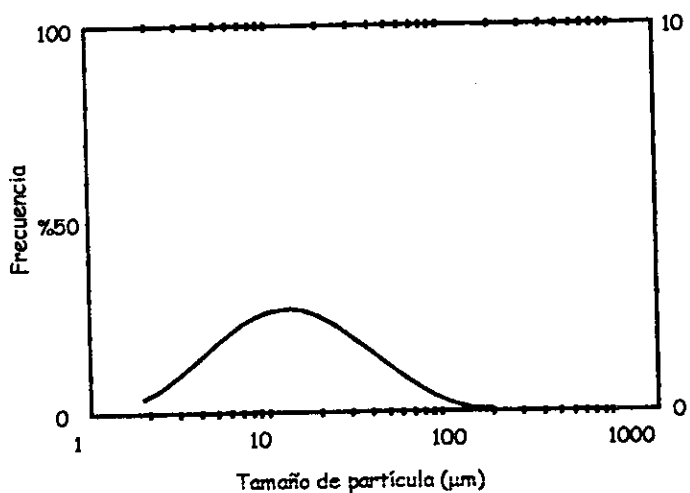
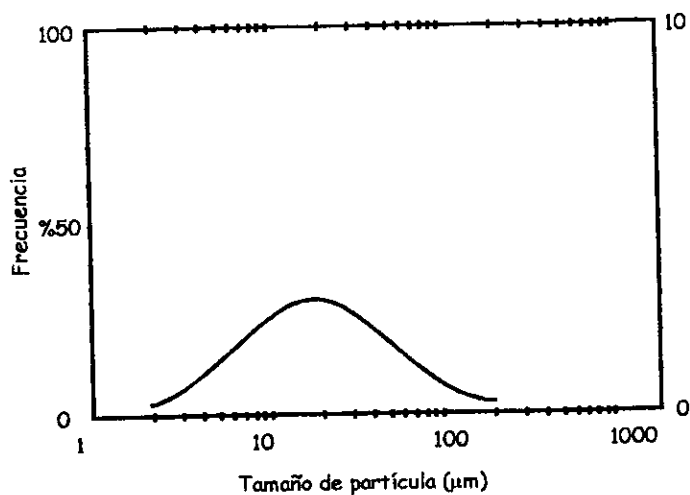
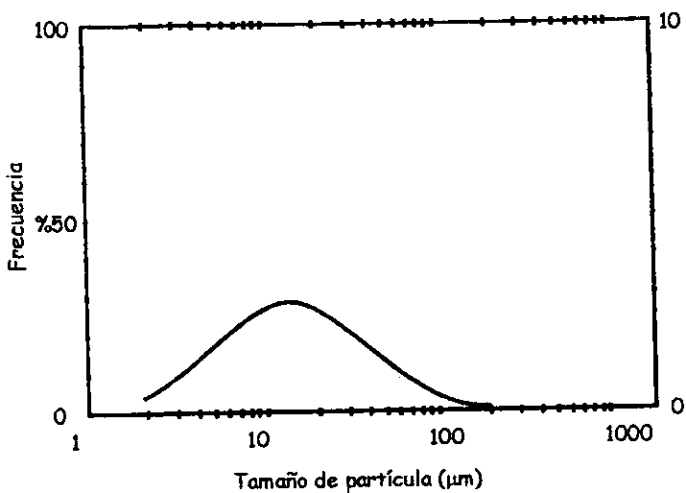
**GA33-GM33-MD33 E-431**  
**Media volumétrica 32.23 µm**

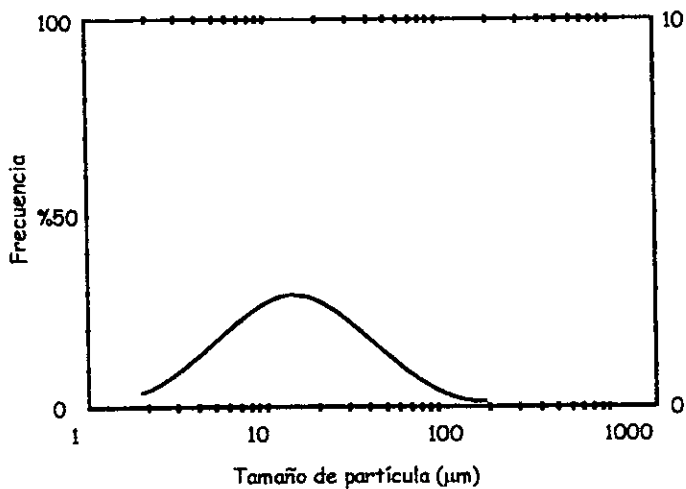


**GA33-GM33-MD33 E-821**  
**Media volumétrica 13.80 µm**

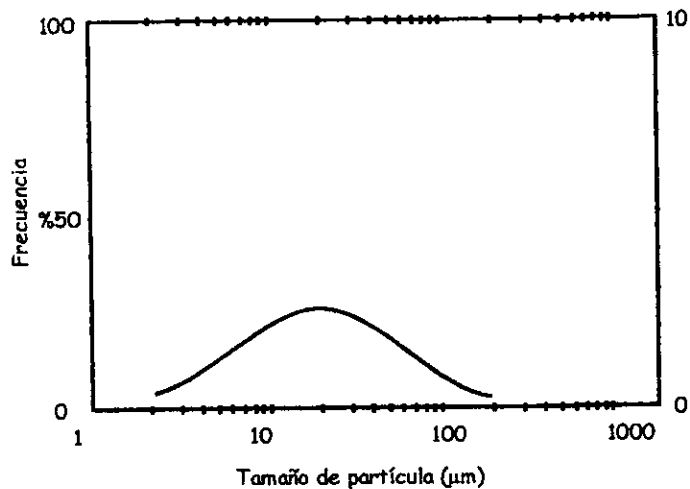


**GA33-GM33-MD33 E-831**  
**Media volumétrica 30.78 µm**

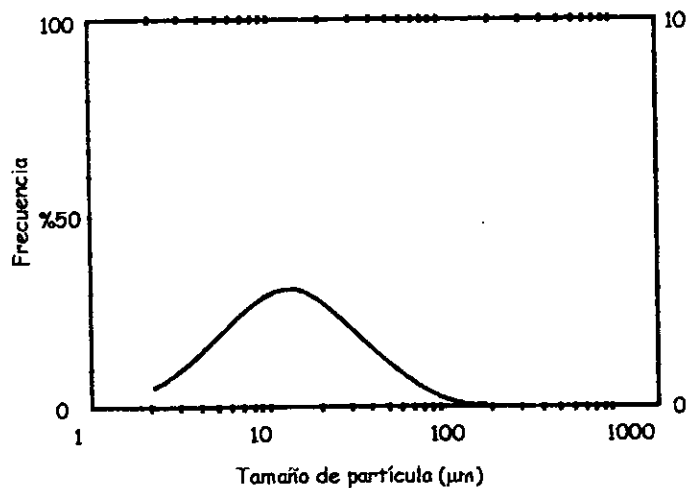




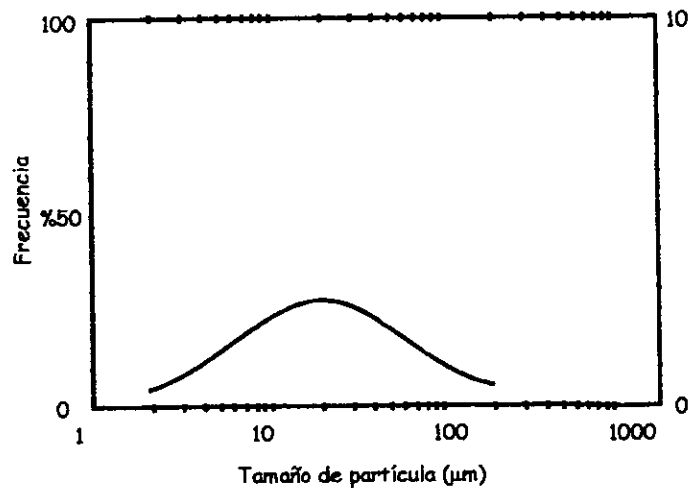
**GA17-GM66-MD17 E-421**  
**Media volumétrica 22.38 µm**



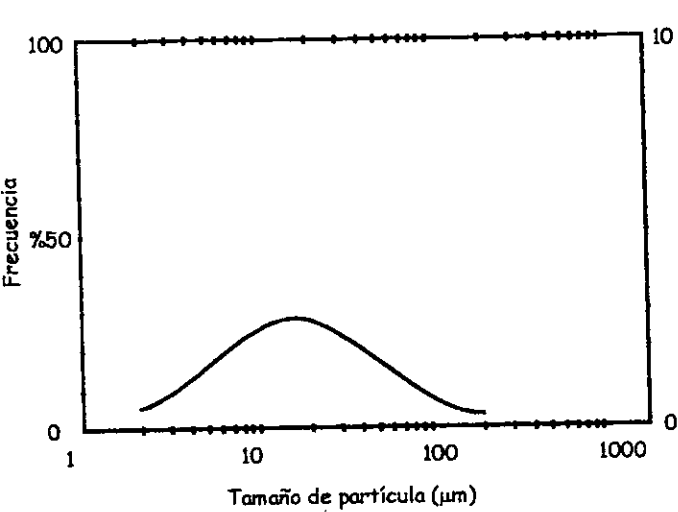
**GA17-GM66-MD17 E-431**  
**Media volumétrica 28.43 µm**



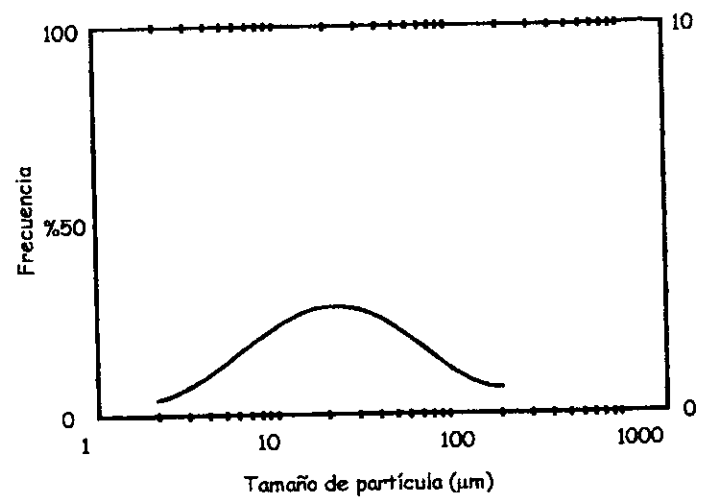
**GA17-GM66-MD17 E-821**  
**Media volumétrica 17.43 µm**



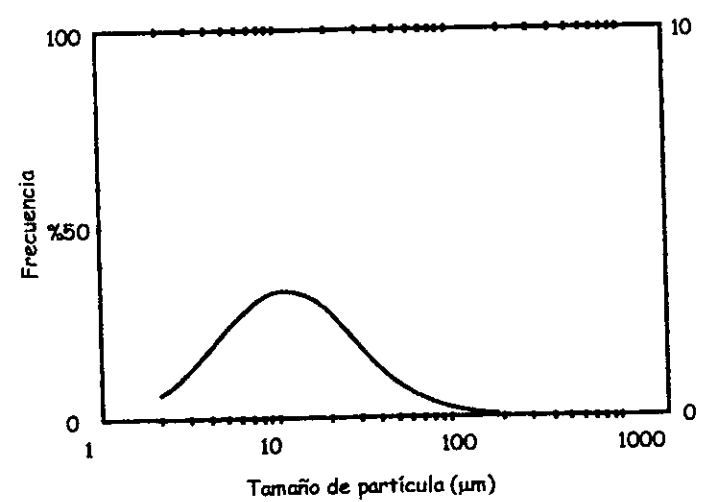
**GA17-GM66-MD17 E-831**  
**Media volumétrica 29.51 µm**



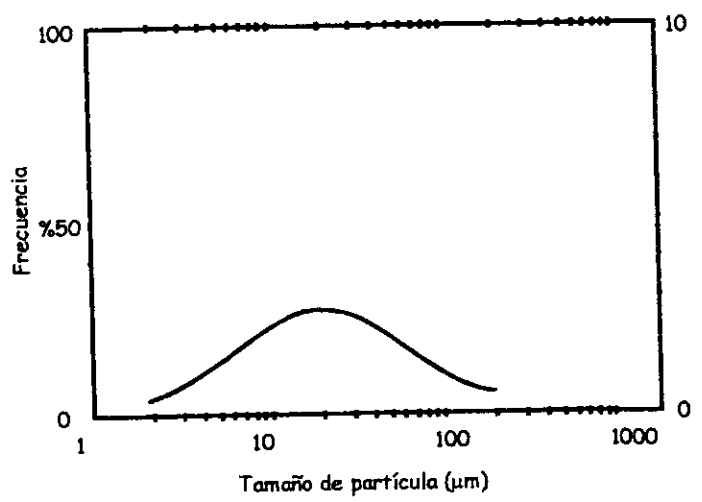
**GA17-GM17-MD66 E-421**  
**Media volumétrica 24.61 µm**



**GA17-GM17-MD66 E-431**  
**Media volumétrica 31.44 µm**



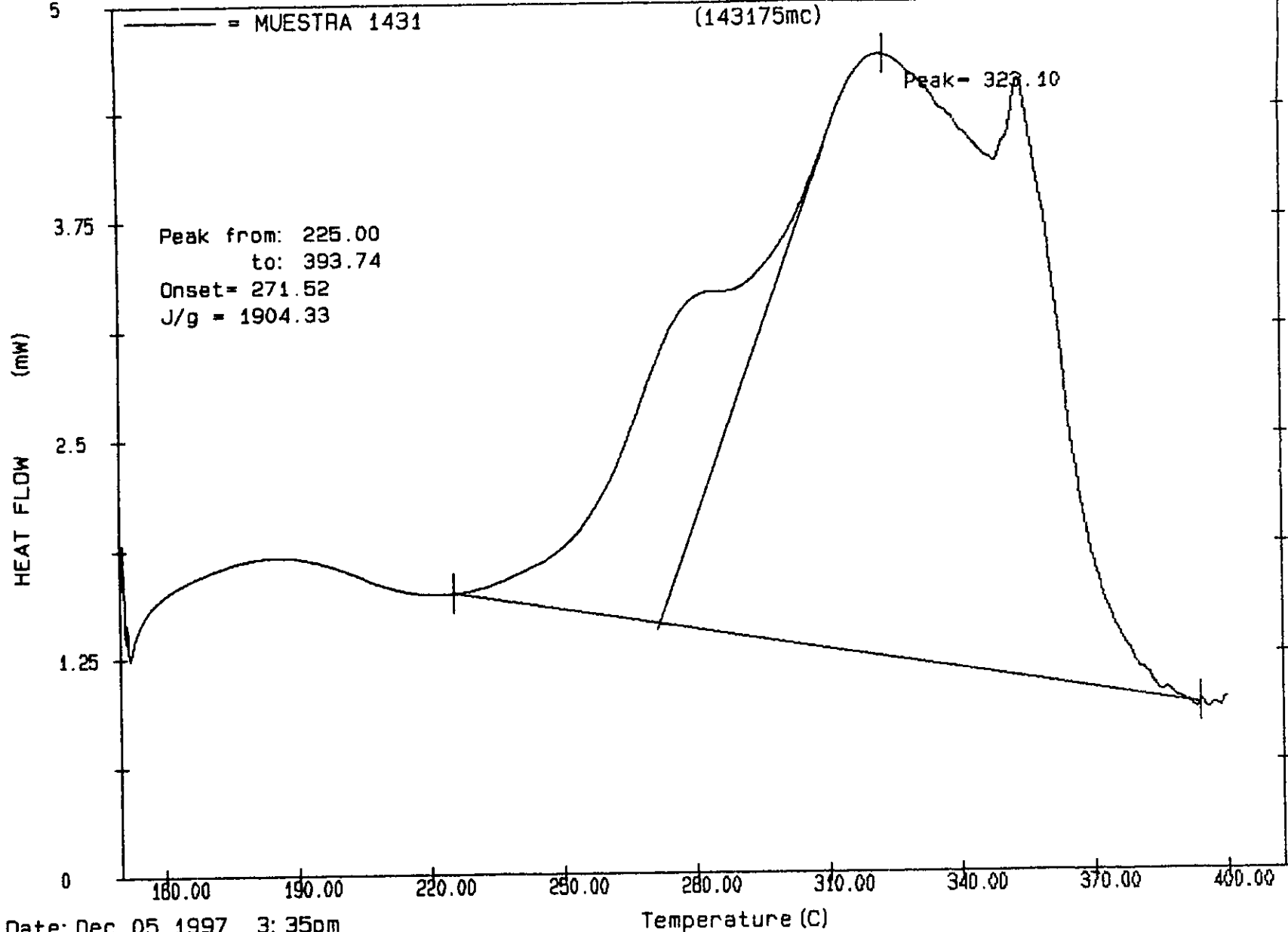
**GA17-GM17-MD66 E-821**  
**Media volumétrica 15.23 µm**



**GA17-GM17-MD66 E831**  
**Media volumétrica 30.04 µm**

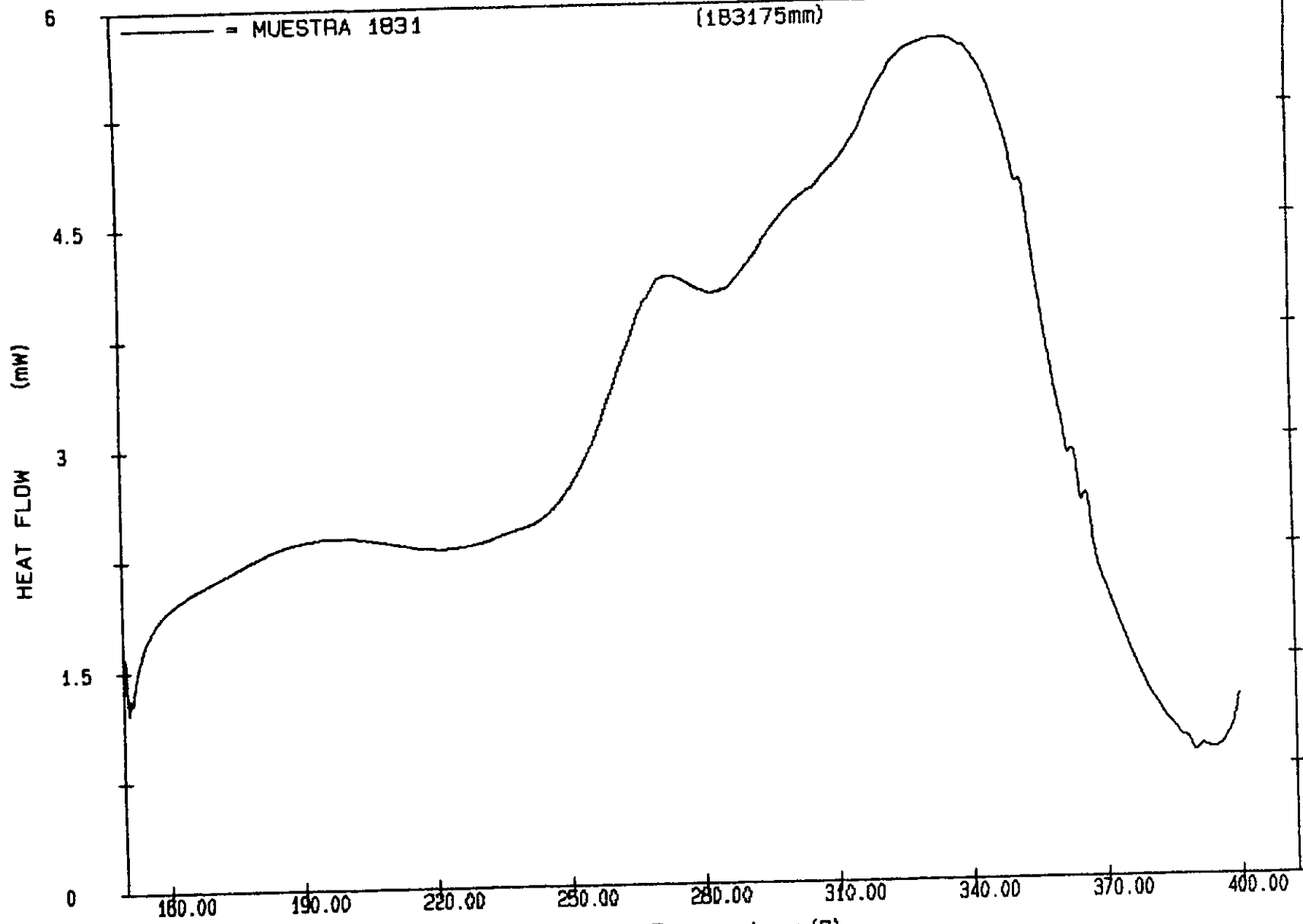


**APÉNDICE 7**  
**Termogramas obtenidos para los diferentes experimentos**



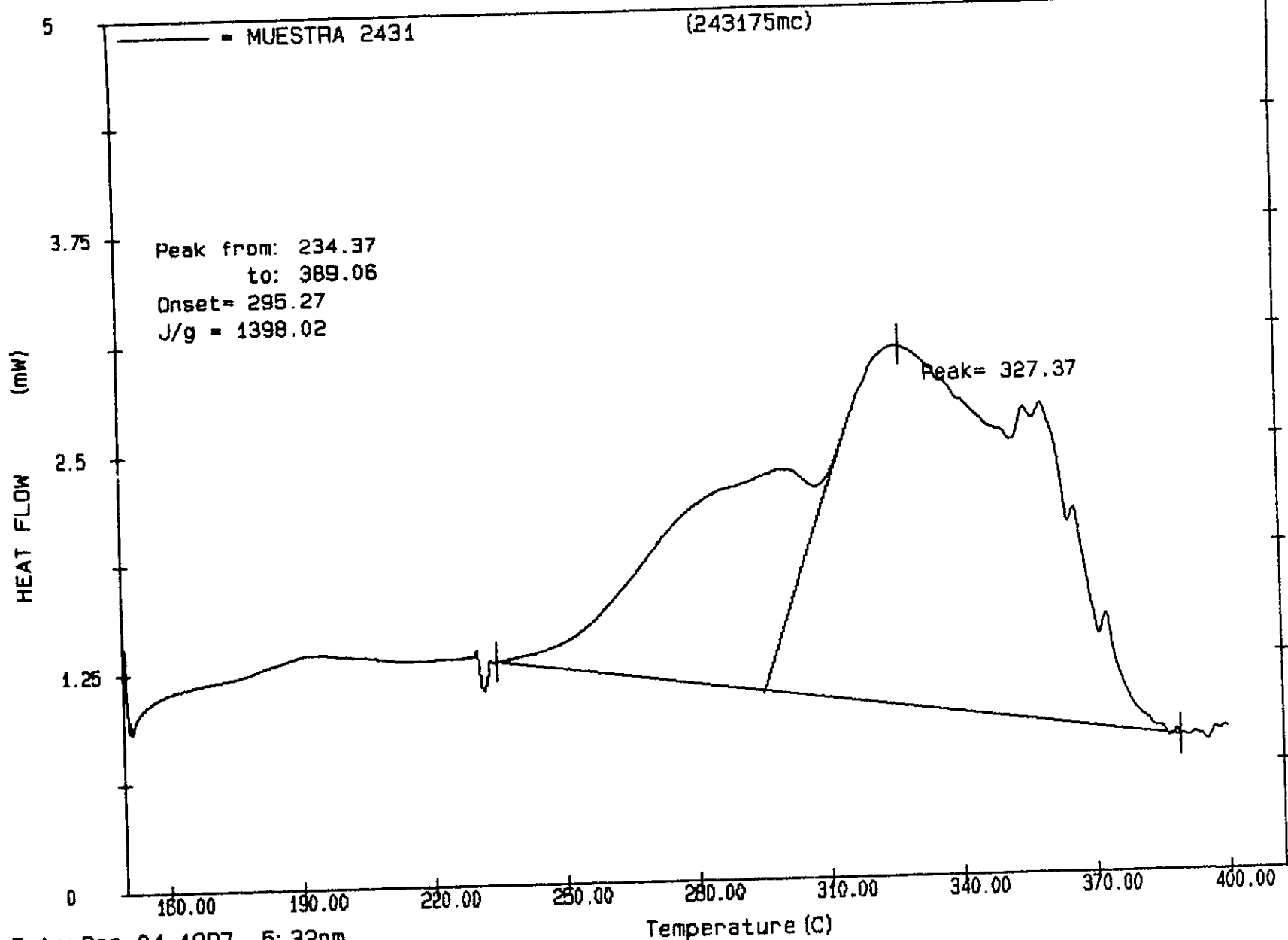
Date: Dec 05, 1997 3: 35pm  
Scanning Rate: 7.5 C/min  
Sample Wt: 1.185 mg Path: A: \  
File 1: 143175MC AVM

PERKIN-ELMER DSC7



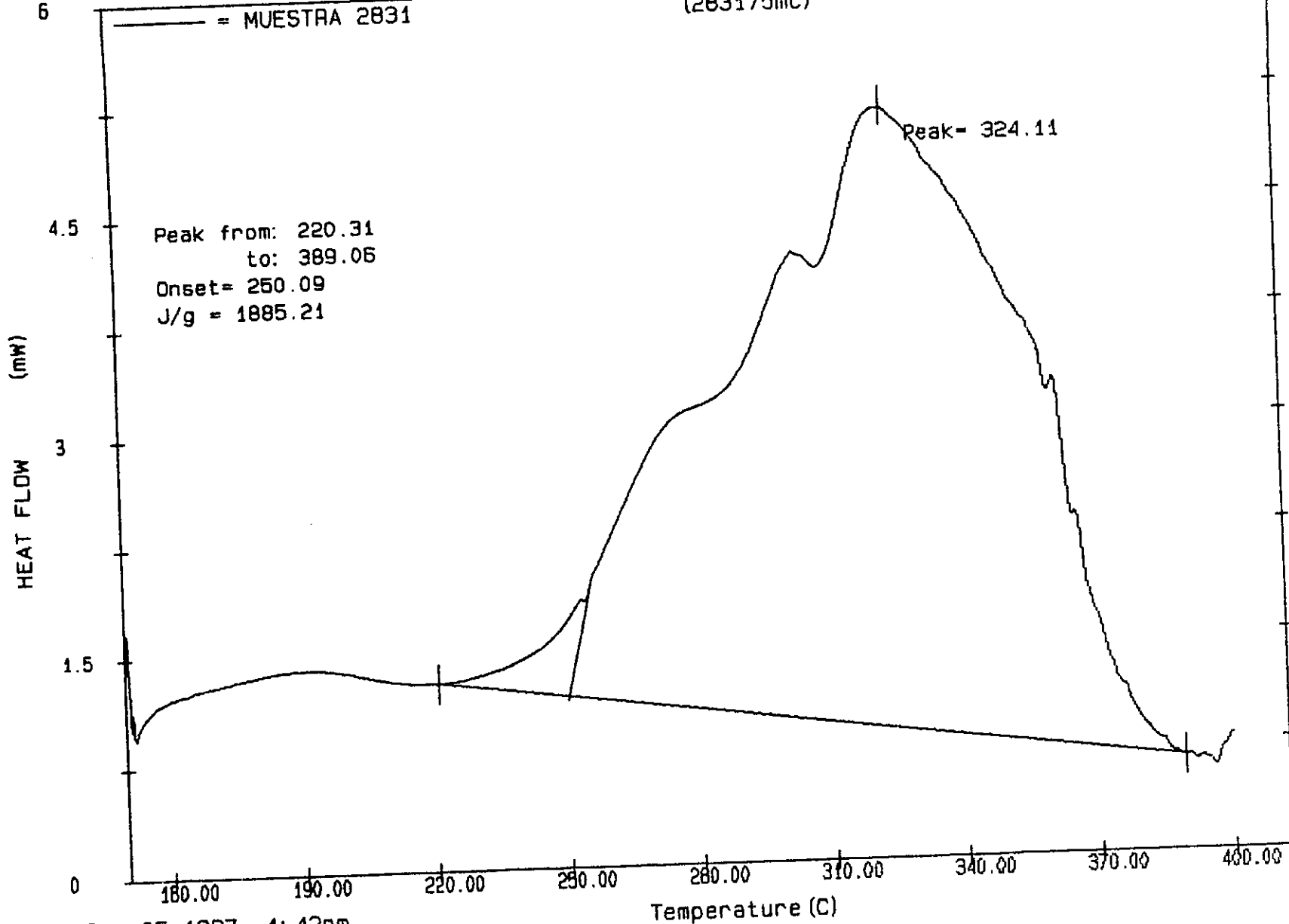
Date: Dec 03, 1997 6: 10pm  
Scanning Rate: 7.5 C/min  
Sample Wt: 1.388 mg Path: a:\  
File 1: 183175MM AVM

PERKIN-ELMER DSC7



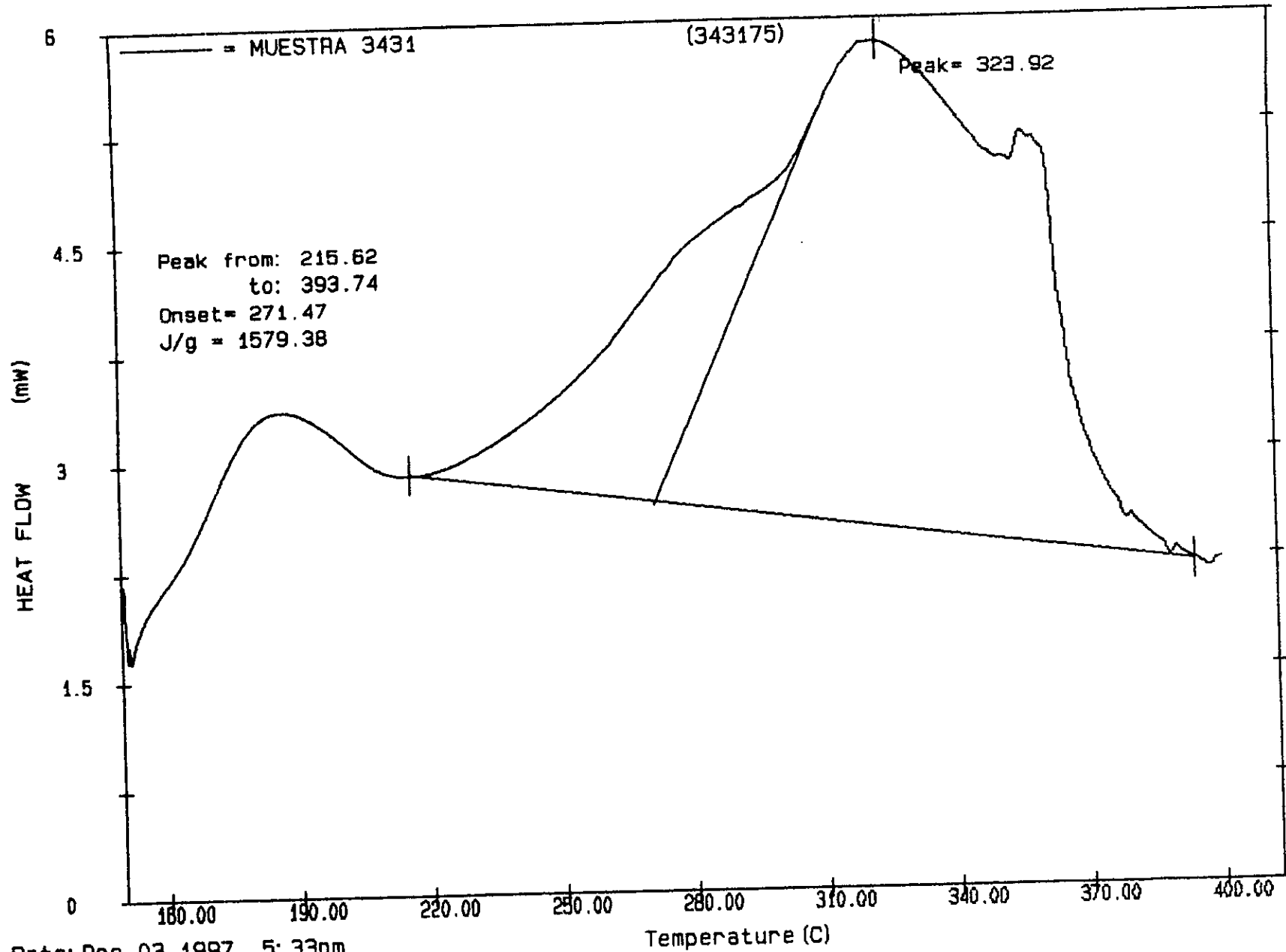
Date: Dec 04, 1997 5: 32pm  
Scanning Rate: 7.5 C/min  
Sample Wt: 0.909 mg Path: a:\  
File 1: 243175MC AVM

PERKIN-ELMER DSC7



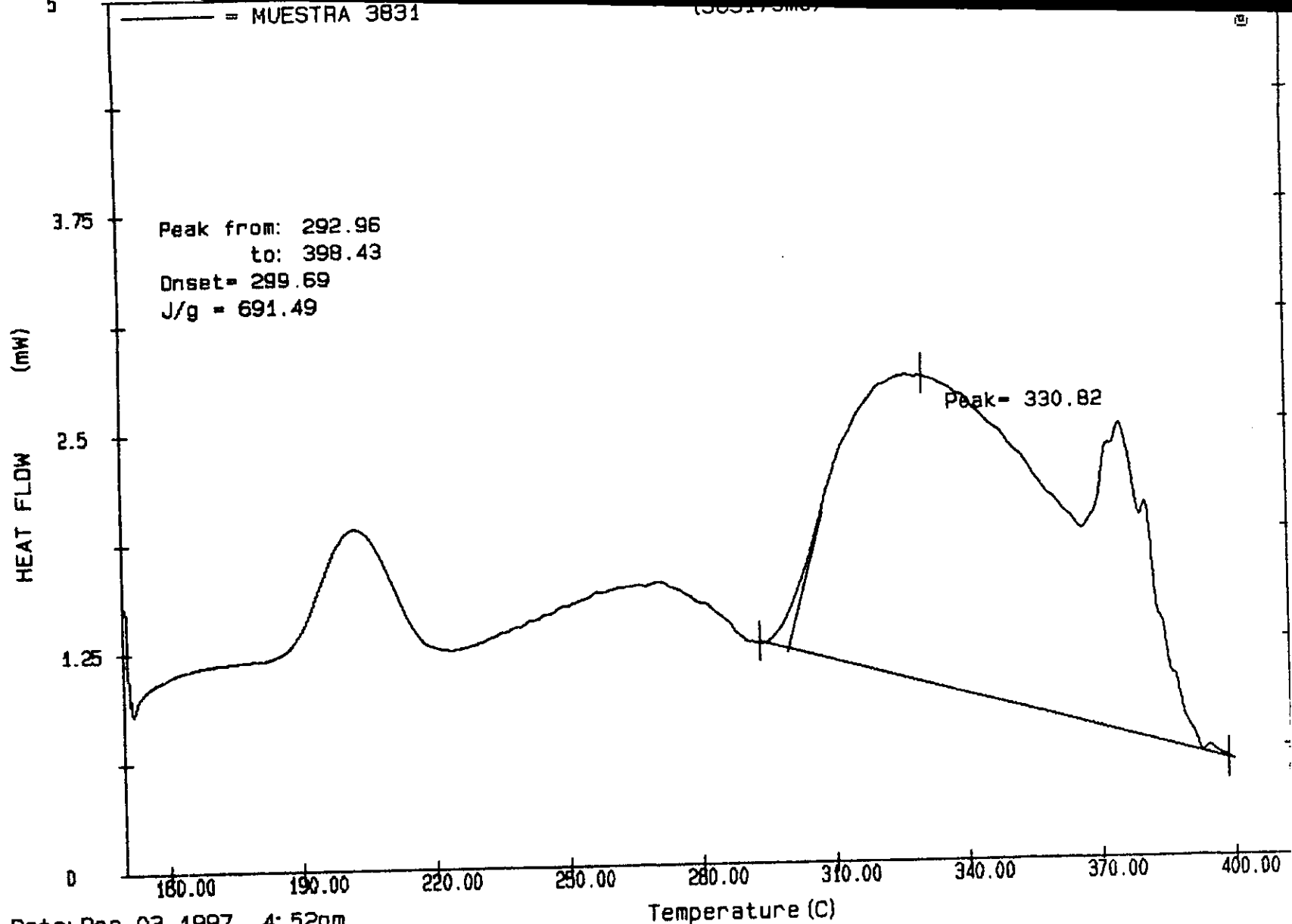
Date: Dec 05, 1997 1:42pm  
Scanning Rate: 7.5 C/min  
Sample Wt: 1.394 mg Path: A:\  
File 1: 283175MC AVM

PERKIN-ELMER DSC7



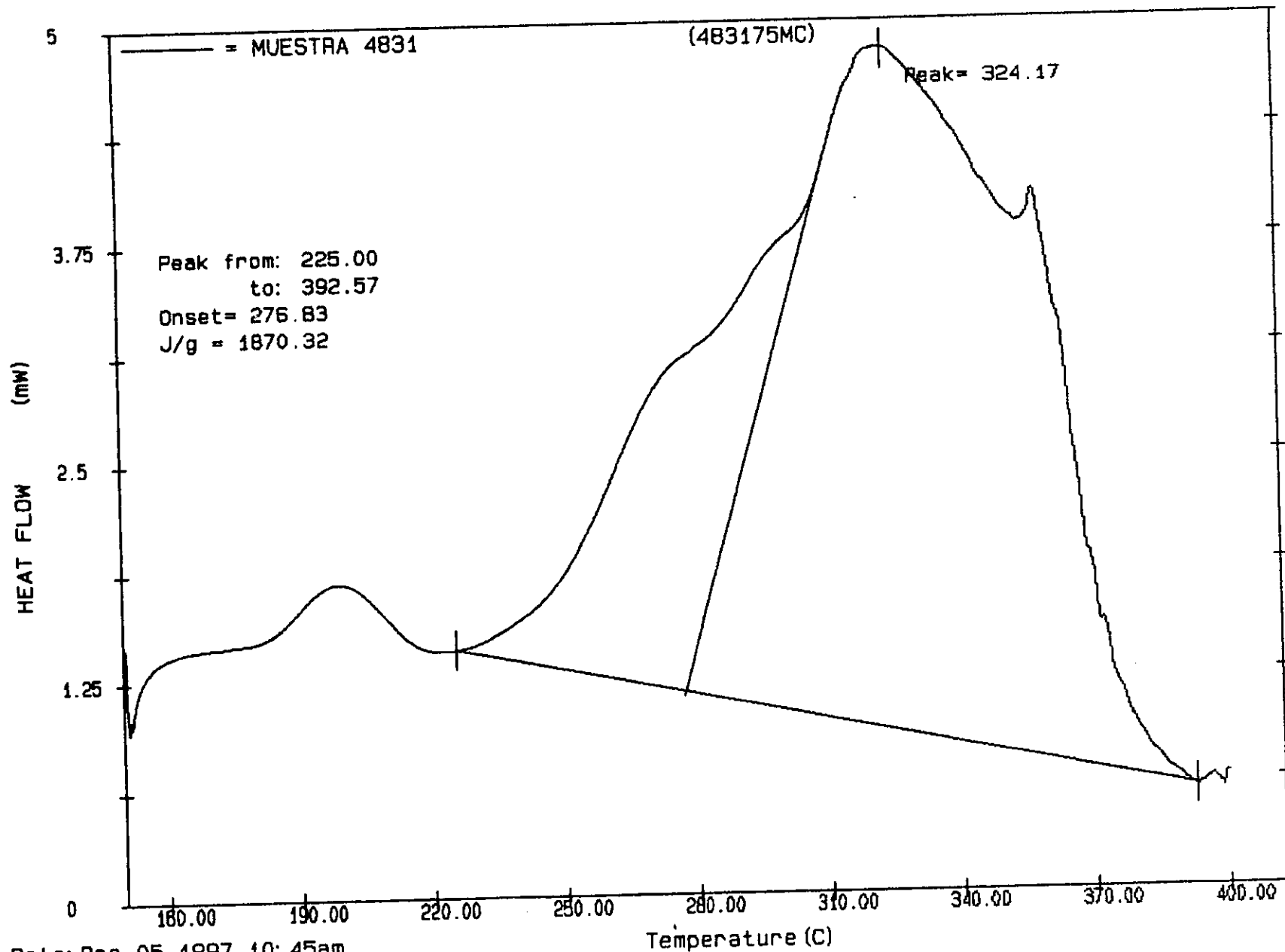
Date: Dec 03, 1997 5: 33pm  
Scanning Rate: 7.5 C/min  
Sample Wt: 1.434 mg Path: a:\  
File 1: 343175 AVM

PERKIN-ELMER DSC7



Date: Dec 03, 1997 4:52pm  
Scanning Rate: 7.5 C/min  
Sample Wt: 1.365 mg Path: a:\  
File 1: 383175MG AVM

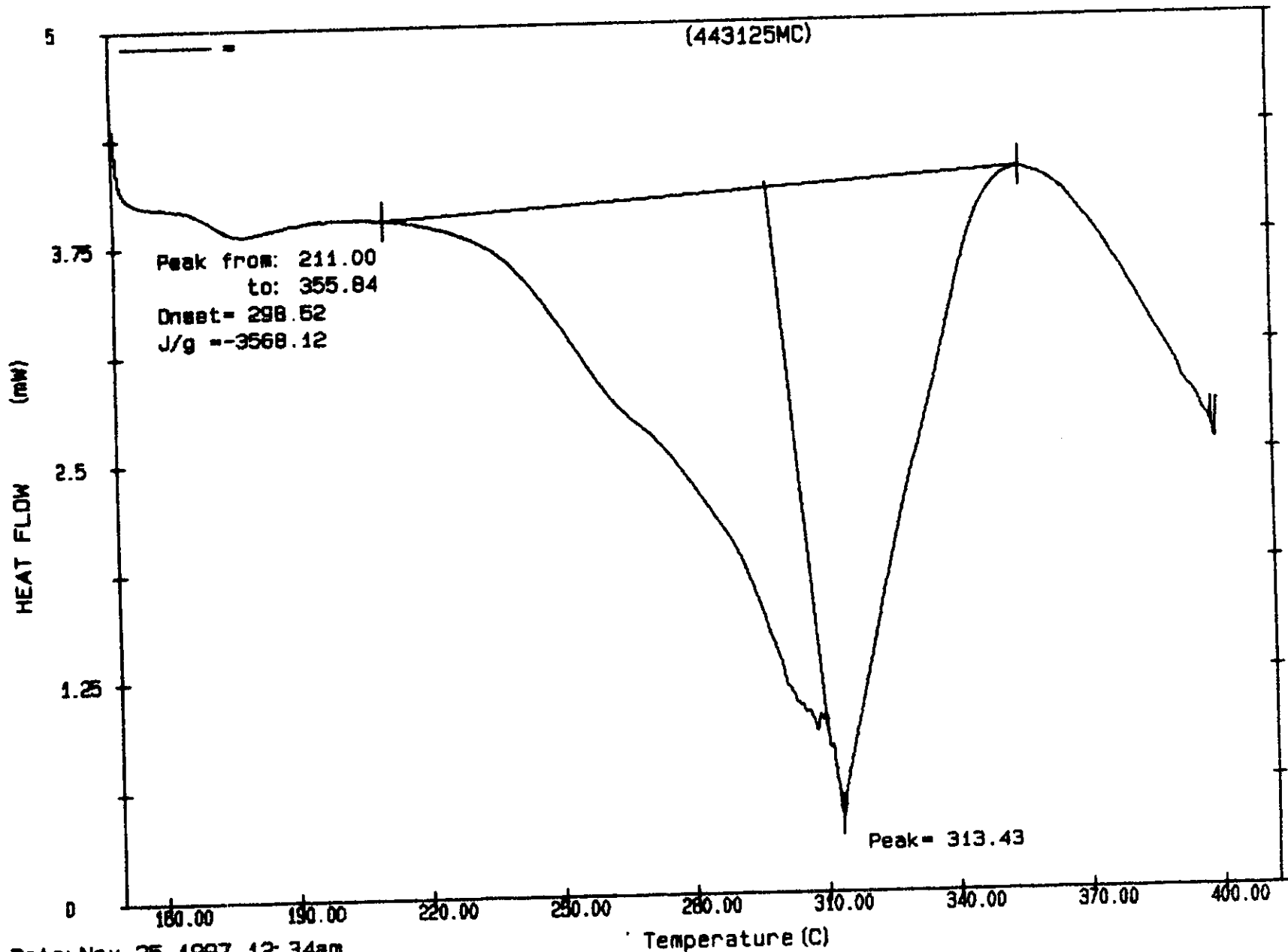
PERKIN-ELMER DSC7



Date: Dec 05, 1997 10: 45am  
 Scanning Rate: 7.5 C/min  
 Sample Wt: 1.382 mg Path: A:\  
 E:\10 4 483175MC 1111

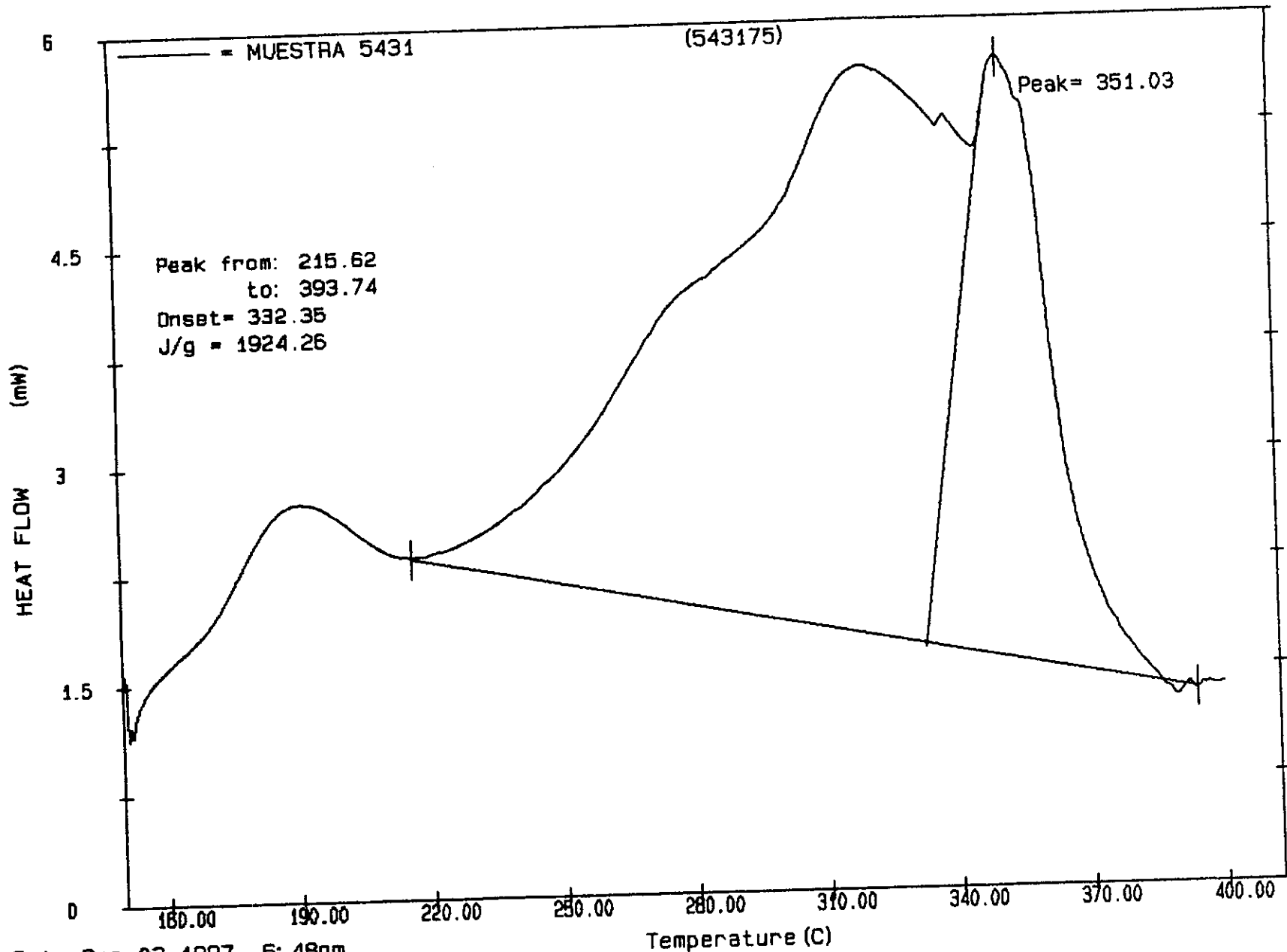
DERKTN-FI MFR DSC7





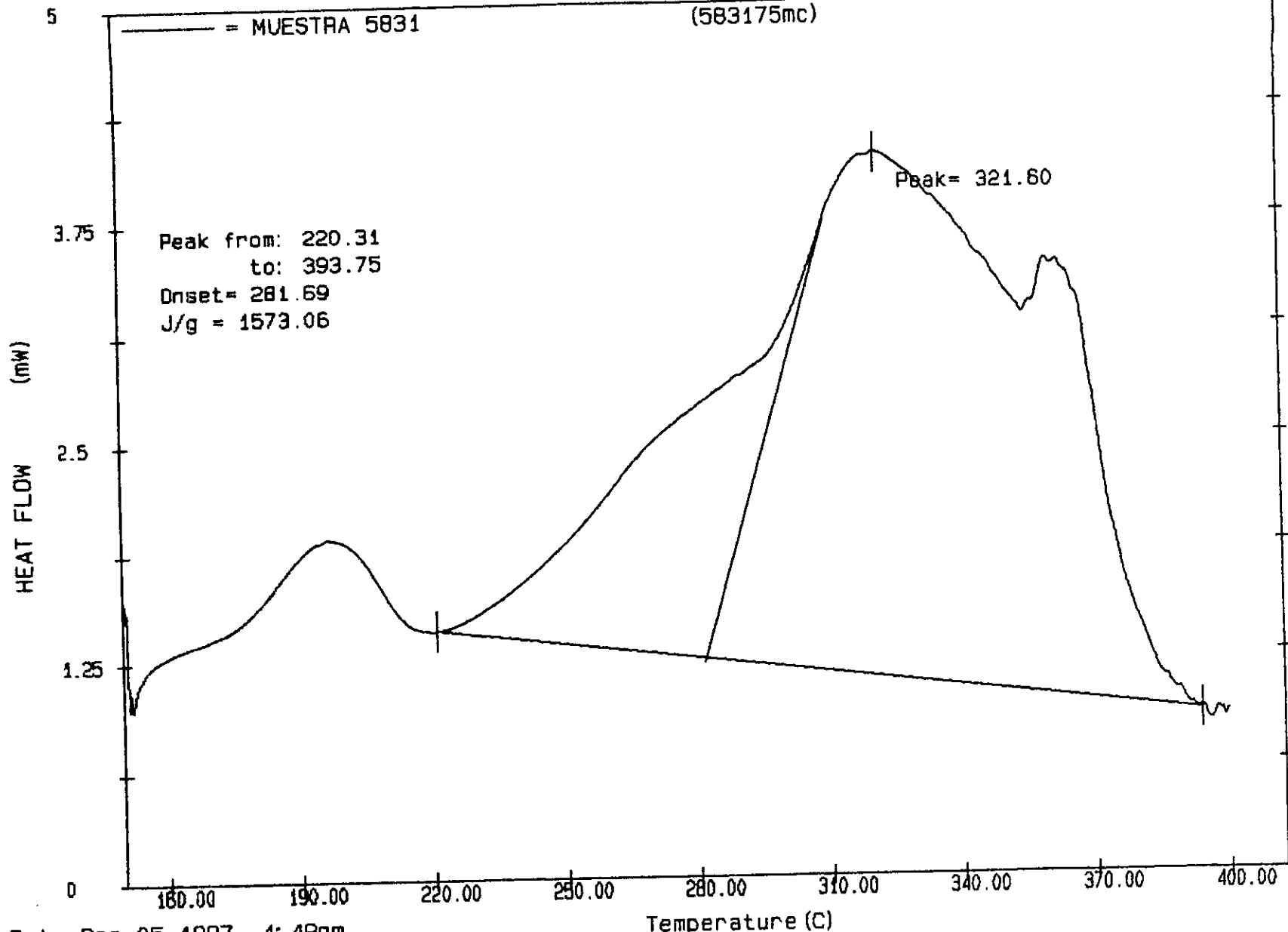
Date: Nov 25, 1997 12:34am  
Scanning Rate: 2.5 C/min  
Sample Wt: 1.244 mg Path: a:\  
File 1: 443125MC

PERKIN-ELMER DSC7



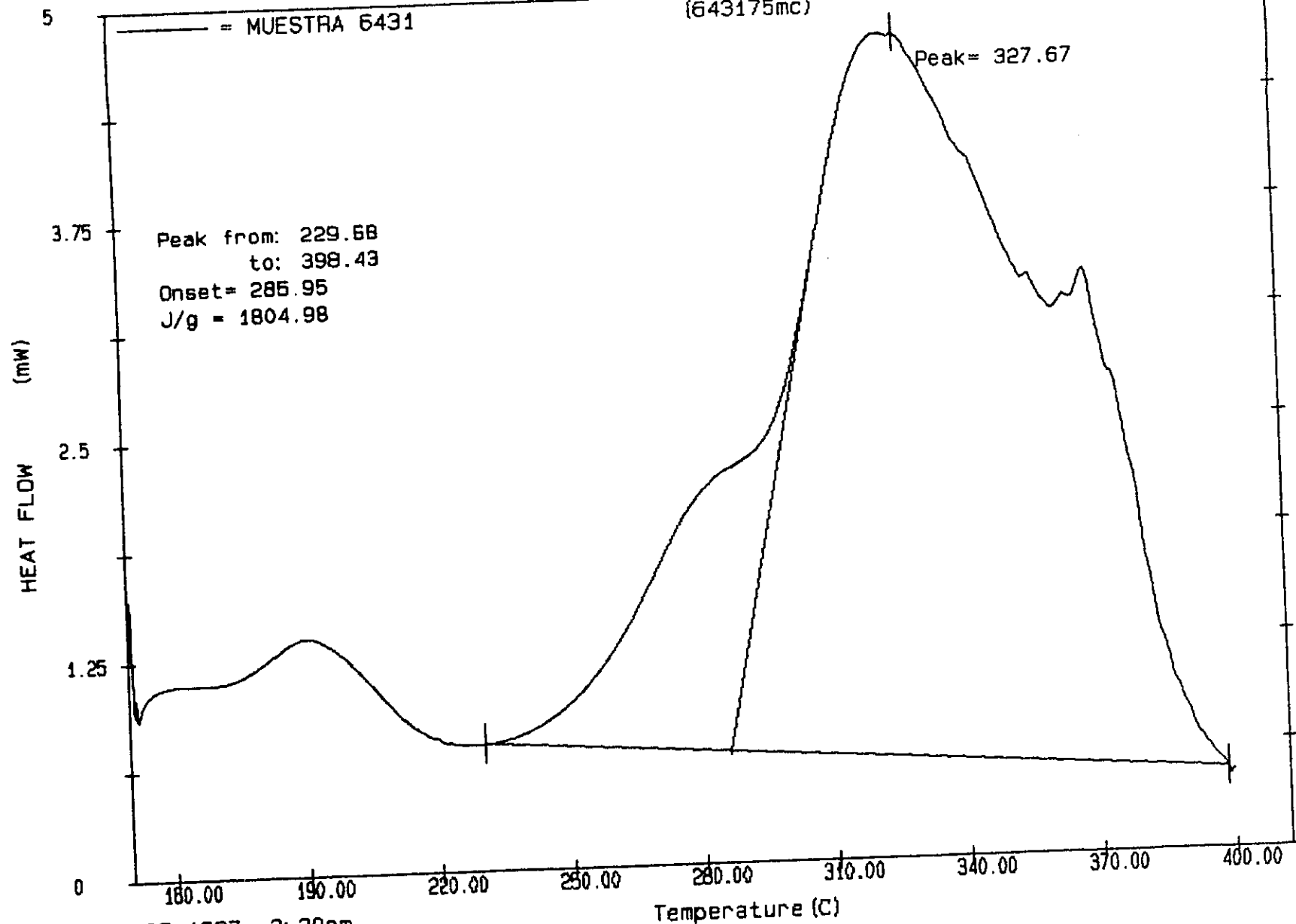
Date: Dec 03, 1997 6: 48pm  
Scanning Rate: 7.5 C/min  
Sample Wt: 1.430 mg Path: a: \  
File 1: 543175 AVM

PERKIN-ELMER DSC7



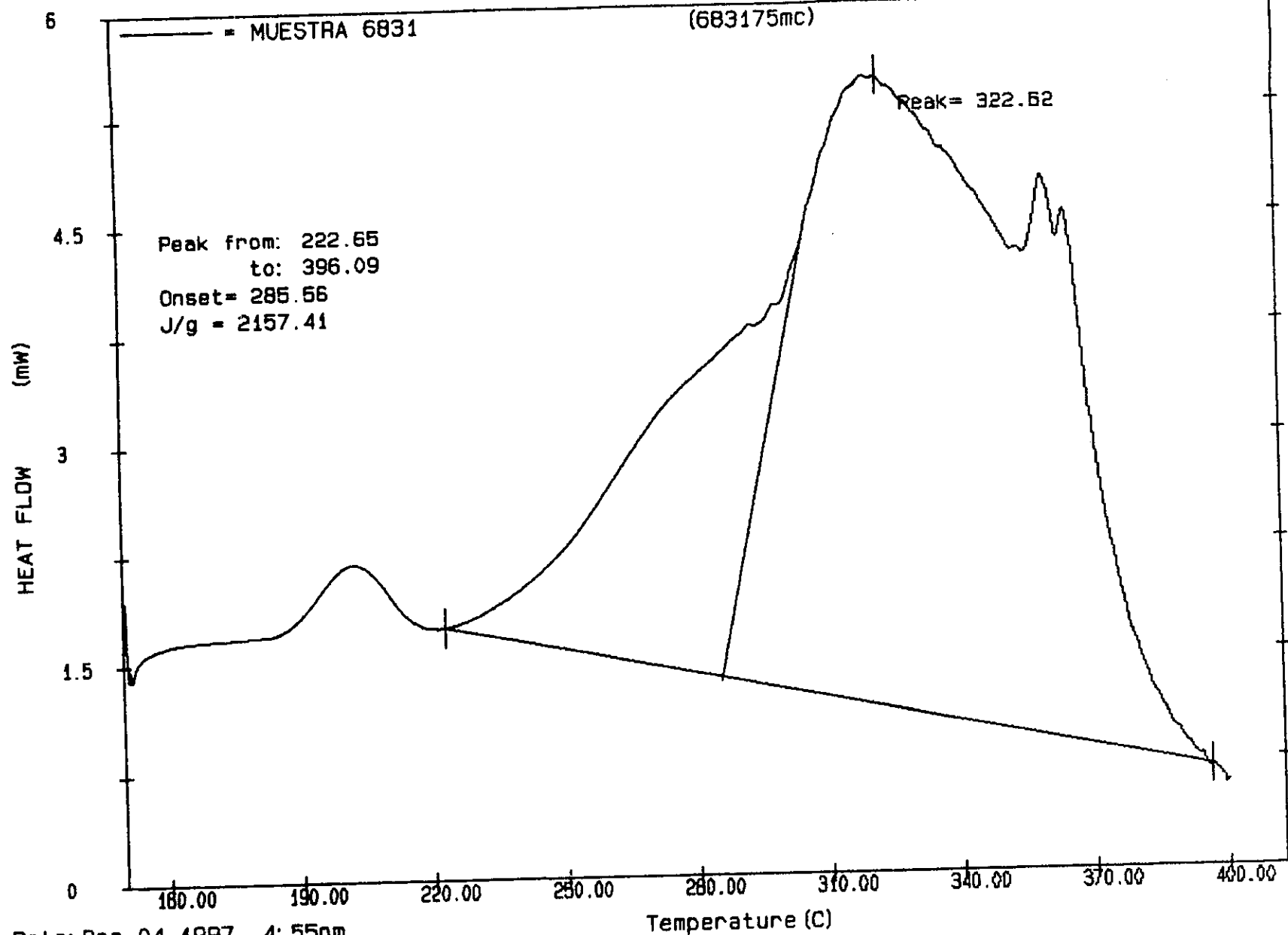
Date: Dec 05, 1997 4: 49pm  
Scanning Rate: 7.5 C/min  
Sample Wt: 1.326 mg Path: A:\  
File 1: 583175MC AVM

PERKIN-ELMER DSC7



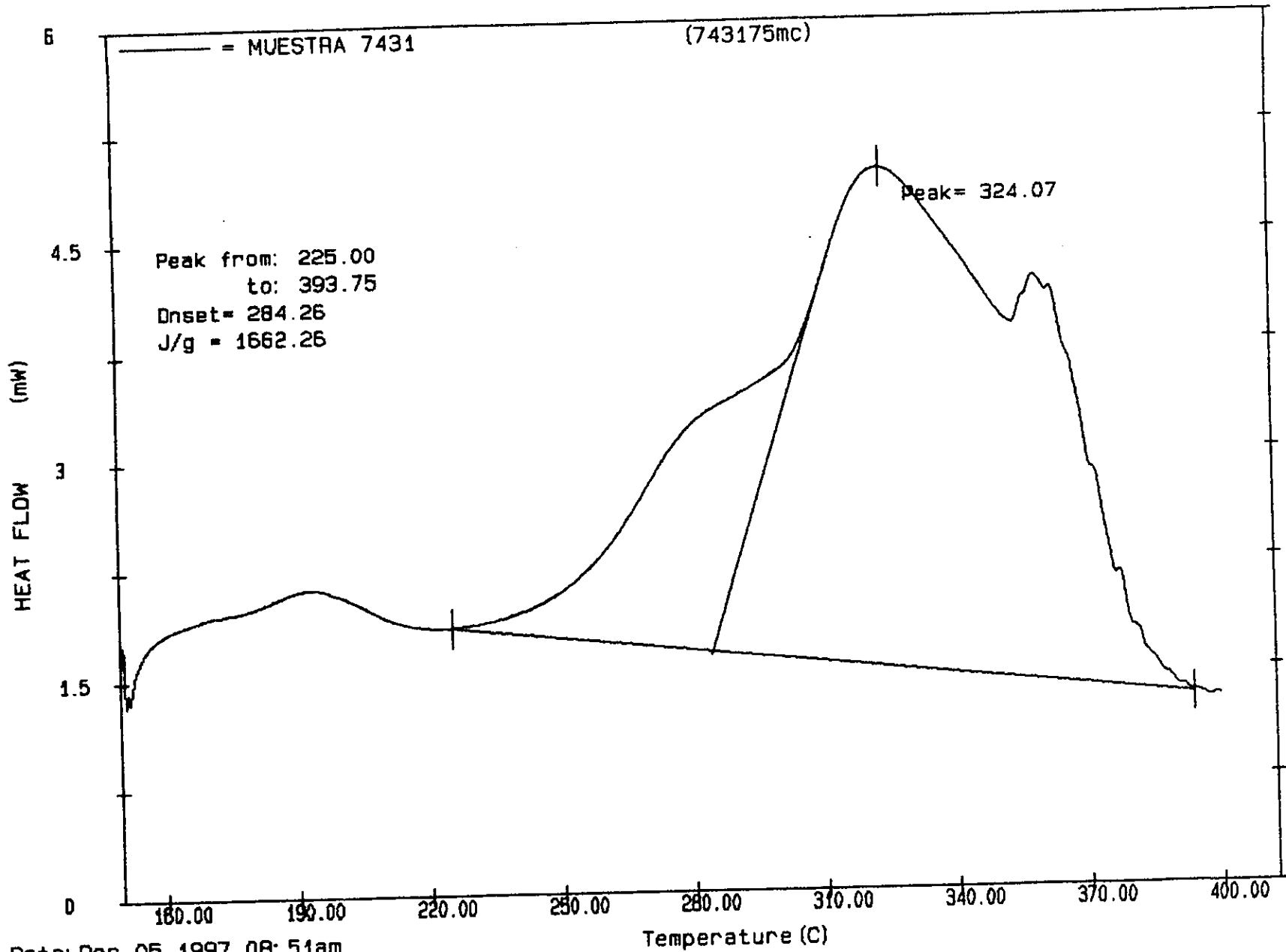
Date: Dec 05, 1997 2: 20pm  
Scanning Rate: 7.5 C/min  
Sample Wt: 1.416 mg Path: A: \  
File 1: 643175MC AVM

PERKIN-ELMER DSC7



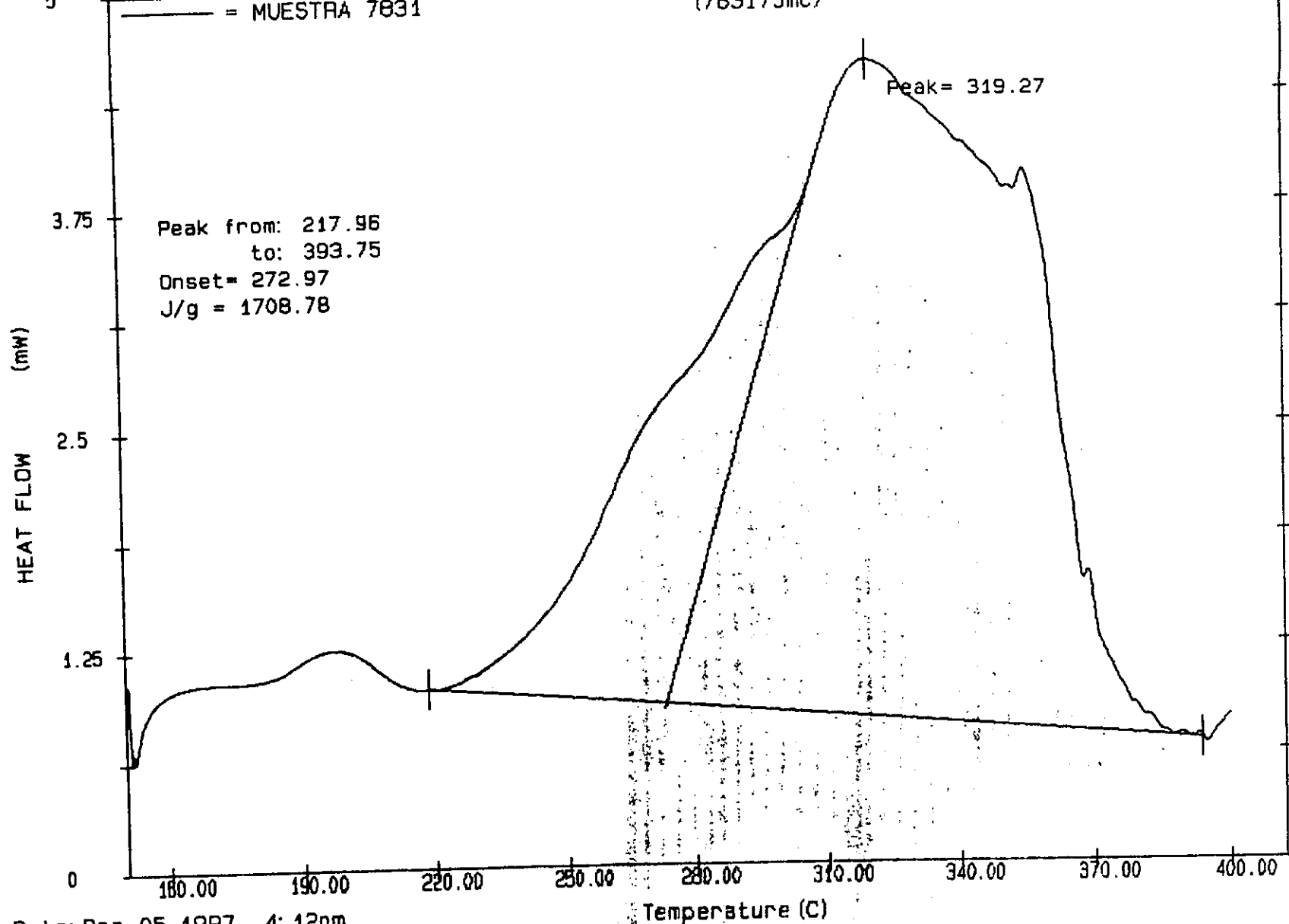
Date: Dec 04, 1997 4: 55pm  
Scanning Rate: 7.5 C/min  
Sample Wt: 1.381 mg Path: a: \  
File 1: 683175MC AVM

PERKIN-ELMER DSC7



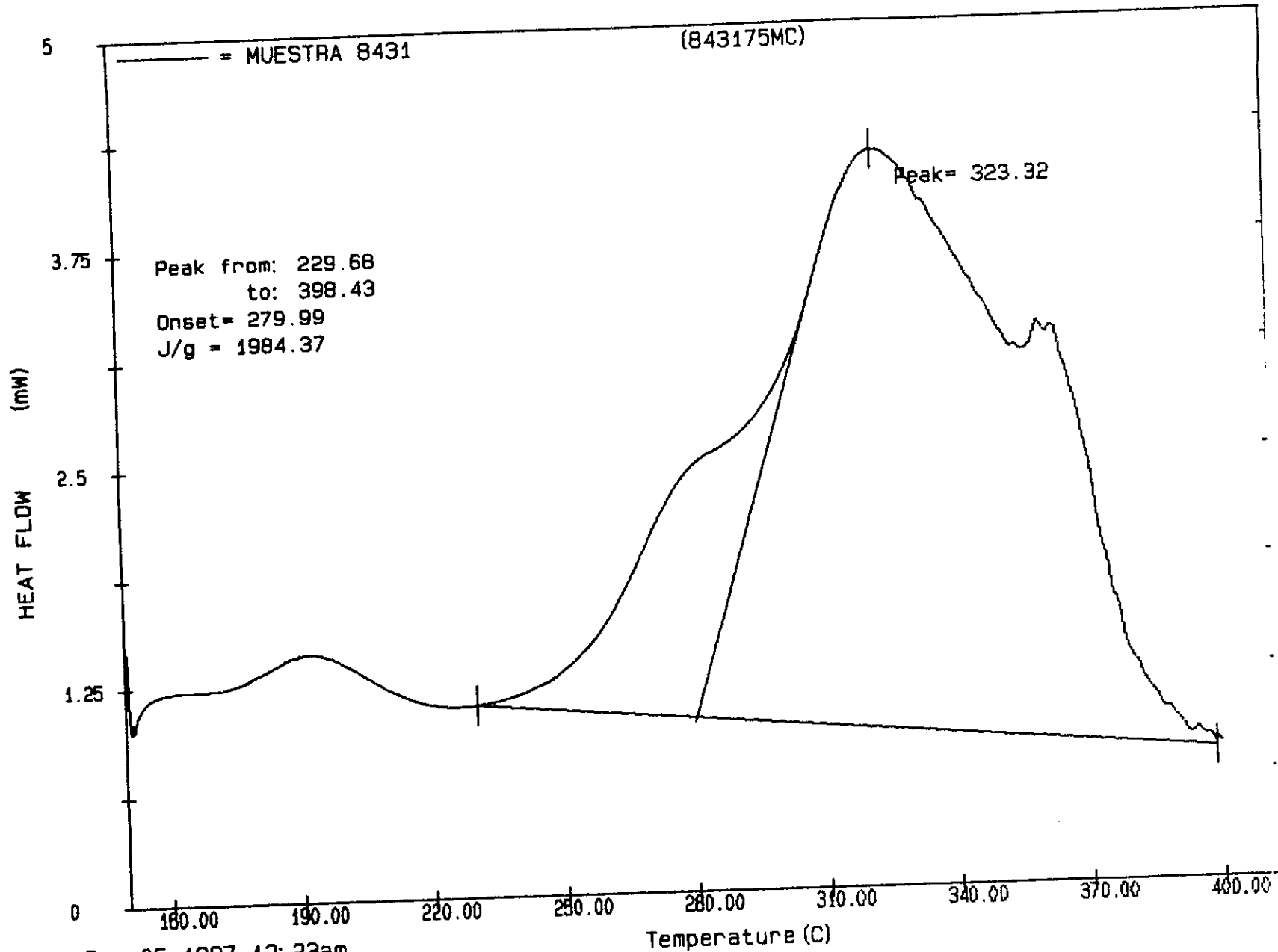
Date: Dec 05, 1997 08: 51am  
Scanning Rate: 7.5 C/min  
Sample Wt: 1.299 mg Path: a:\  
File 1: 743175MG AVM

PERKIN-ELMER DSC7



Date: Dec 05, 1997 4:12pm  
Scanning Rate: 7.5 C/min  
Sample Wt: 1.452 mg Path: A: \\  
File 1: 783175MC AVM

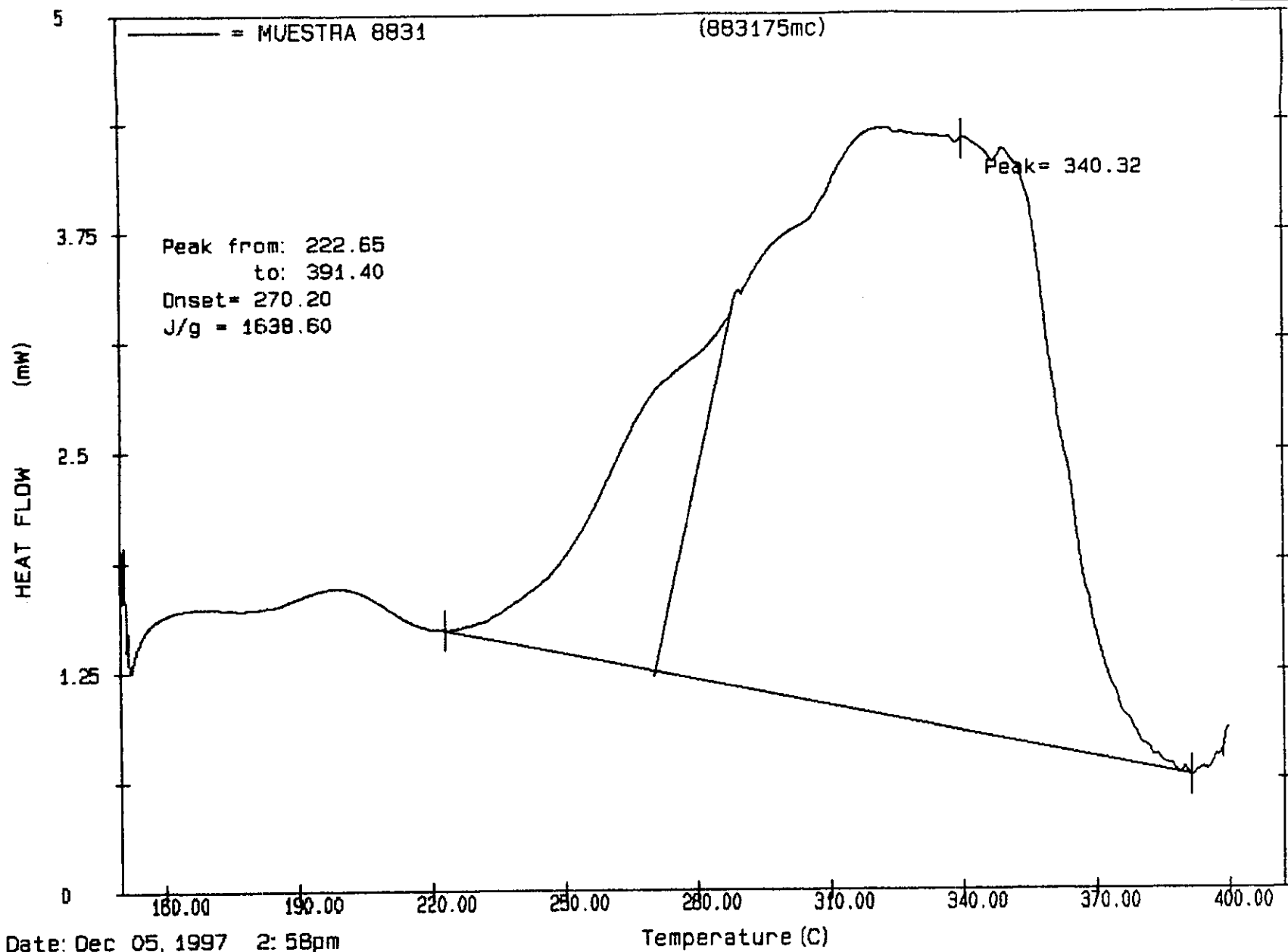
PERKIN-ELMER DSC7



Date: Dec 05, 1997 12: 23am  
Scanning Rate: 7.5 C/min  
Sample Wt: 1.041 mg Path: A: \  
File 1: 843175MC AVM

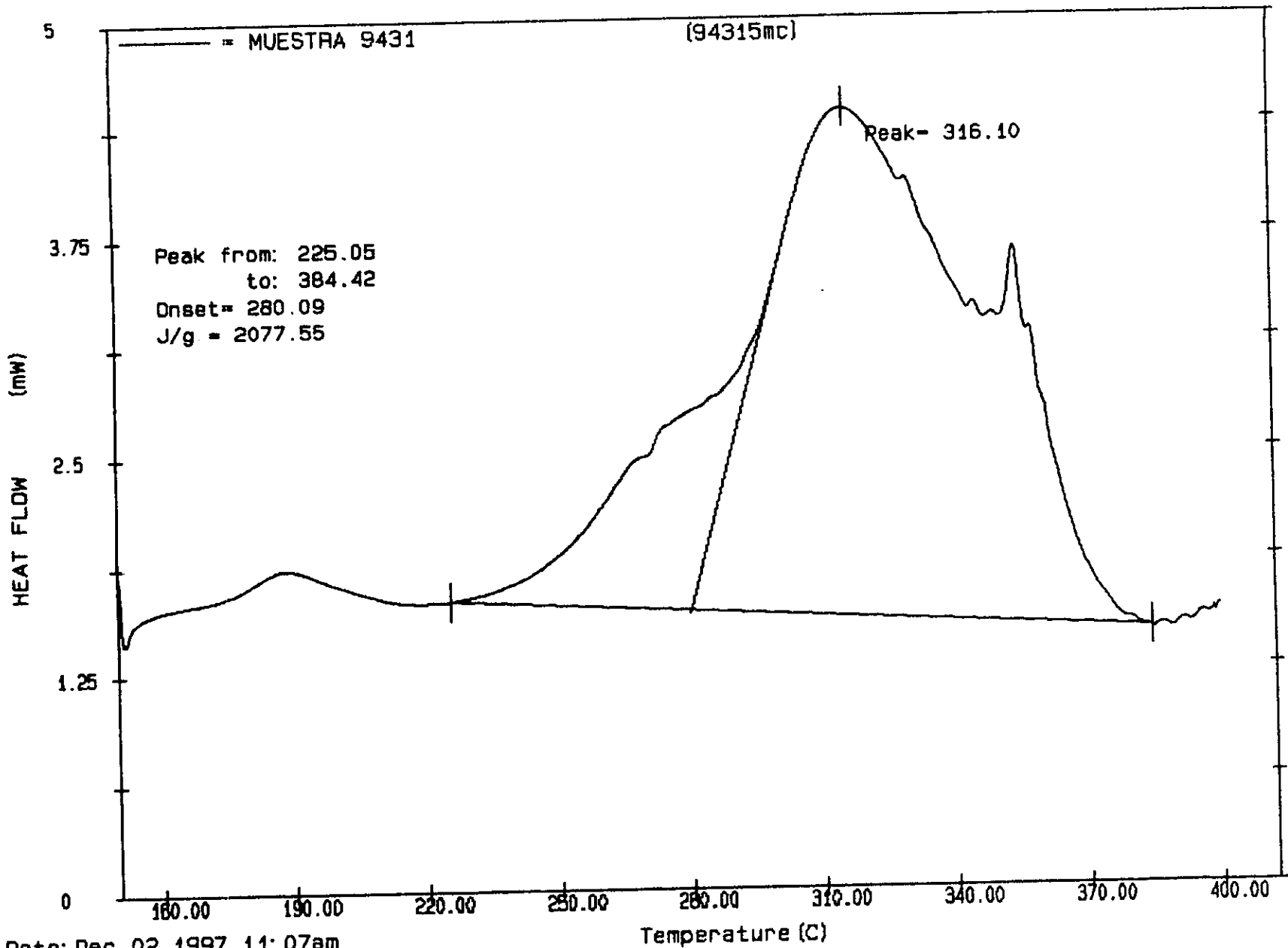
PERKIN-ELMER DSC7





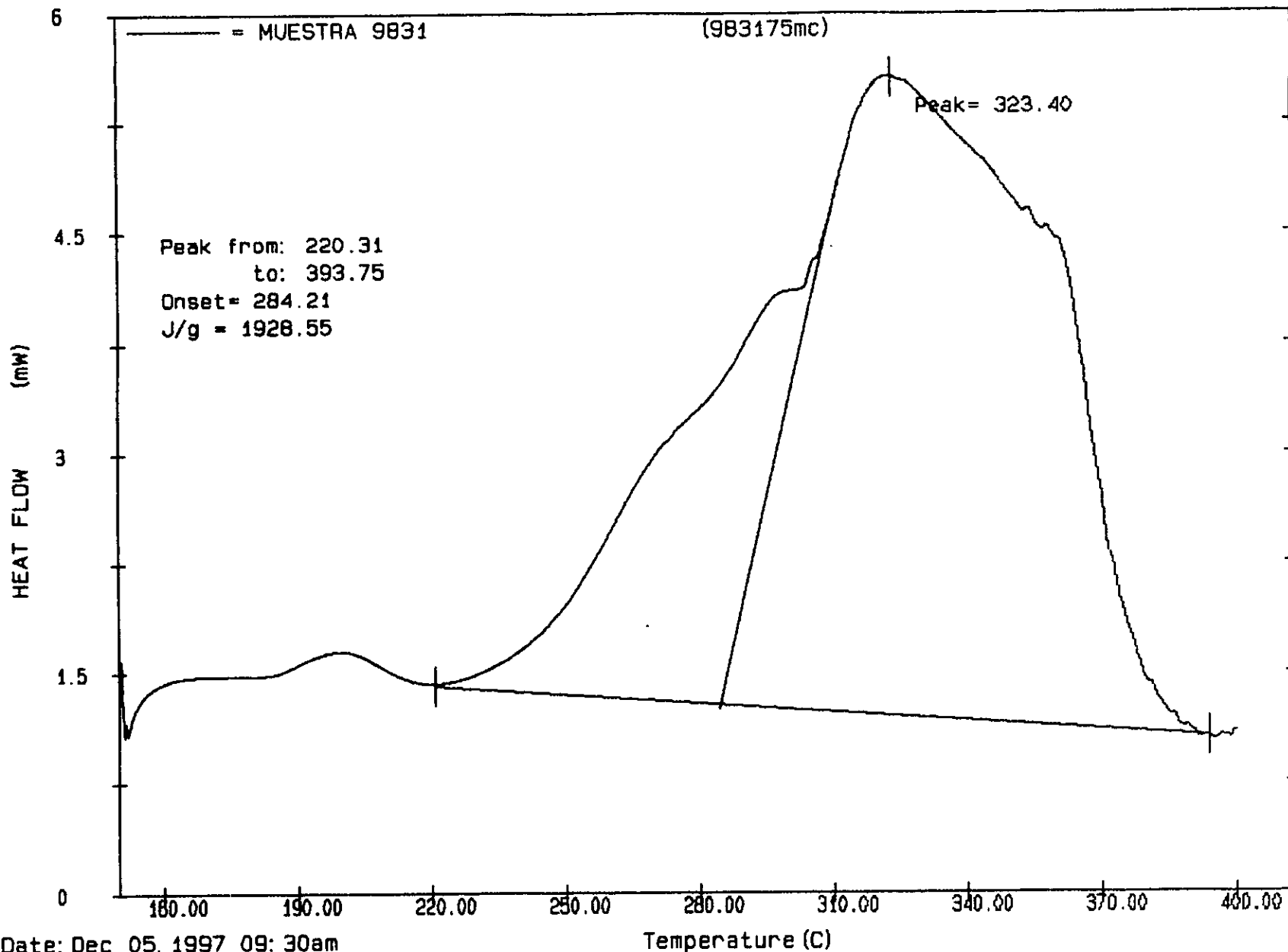
Date: Dec 05, 1997 2: 58pm  
Scanning Rate: 7.5 C/min  
Sample Wt: 1.441 mg Path: A:\  
File 1: 883175MC AVN

PERKIN-ELMER DSC7



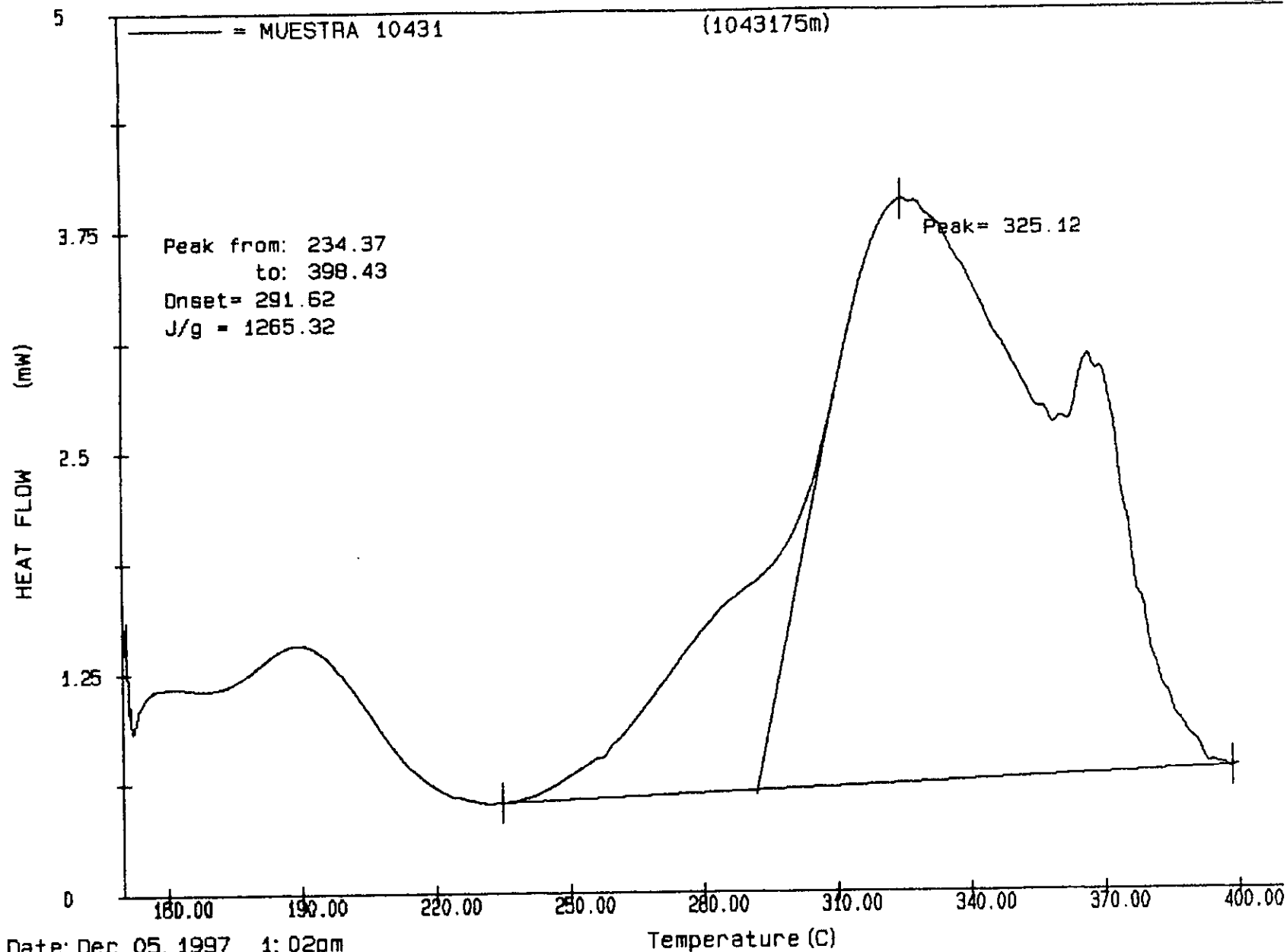
Date: Dec 02, 1997 11: 07am  
Scanning Rate: 5.0 C/min  
Sample Wt: 1.153 mg Path: a: \  
File 1: 94315MC AVM

PERKIN-ELMER DSC7



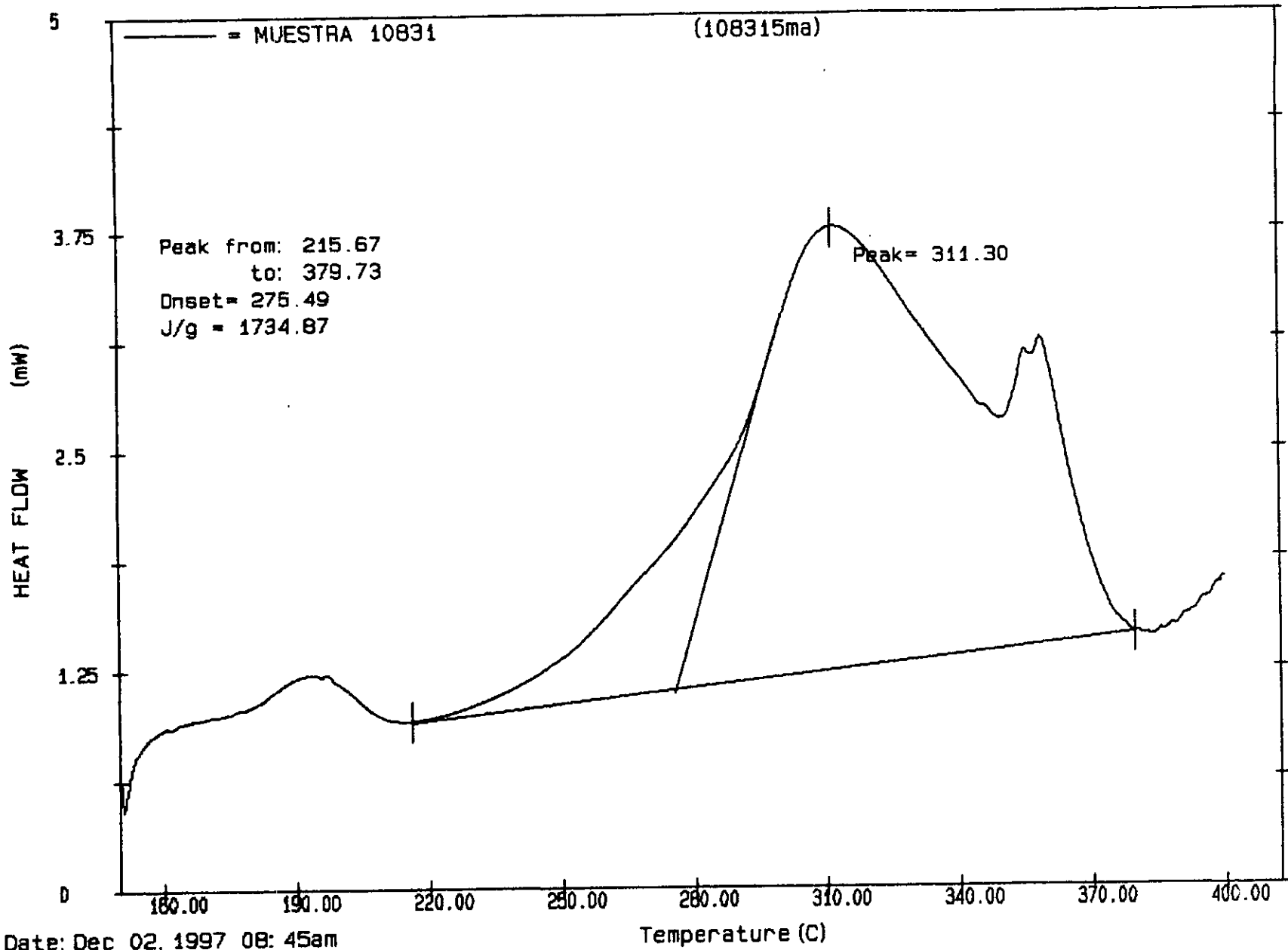
Date: Dec 05, 1997 09: 30am  
Scanning Rate: 7.5 C/min  
Sample Wt: 1.482 mg Path: a:\  
File 1: 983175MC AVM

PERKIN-ELMER DSC7



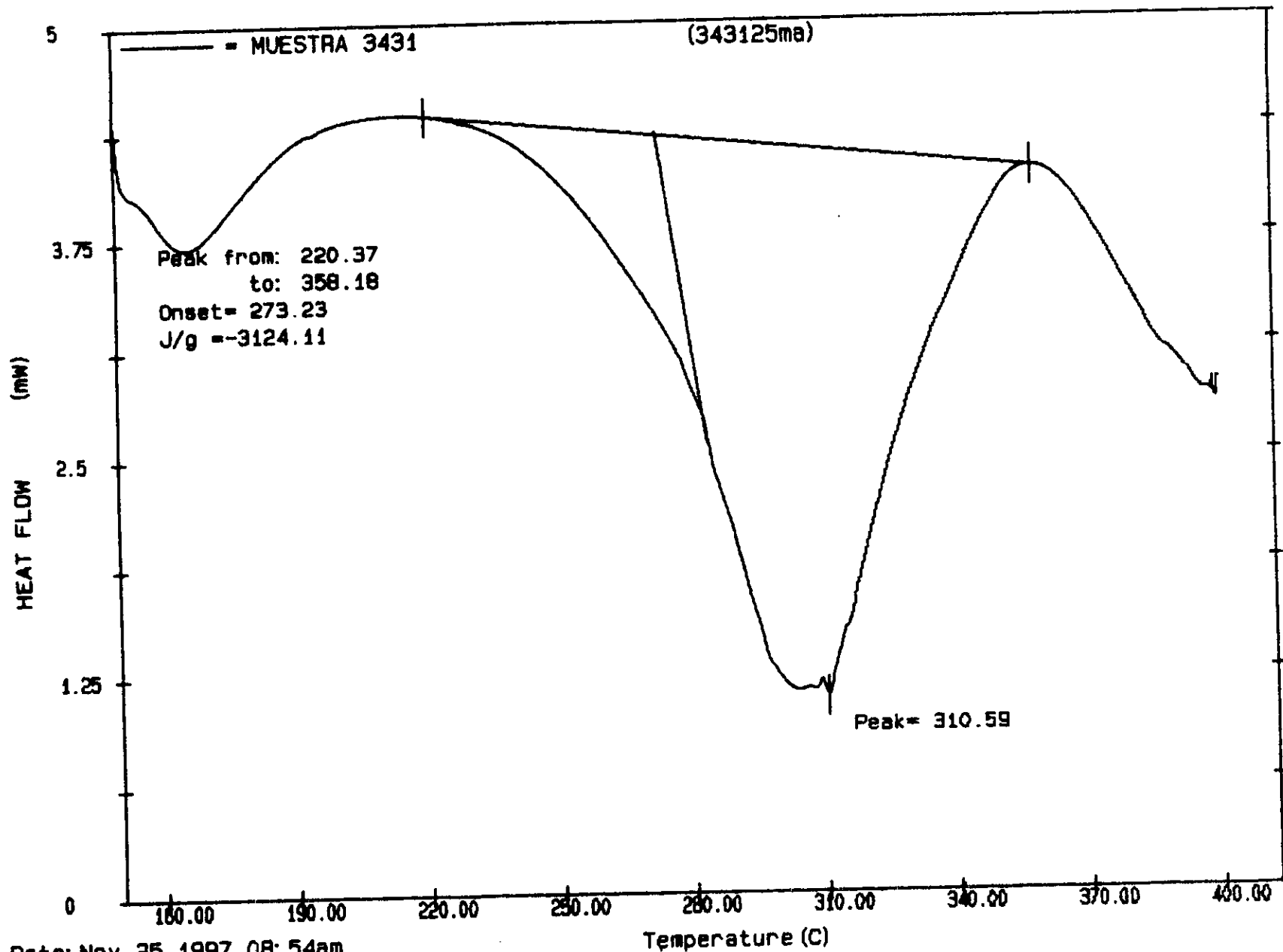
Date: Dec 05, 1997 1:02pm  
Scanning Rate: 7.5 C/min  
Sample Wt: 1.492 mg Path: A:\  
File 1: 1043175M AVM

PERKIN-ELMER DSC7



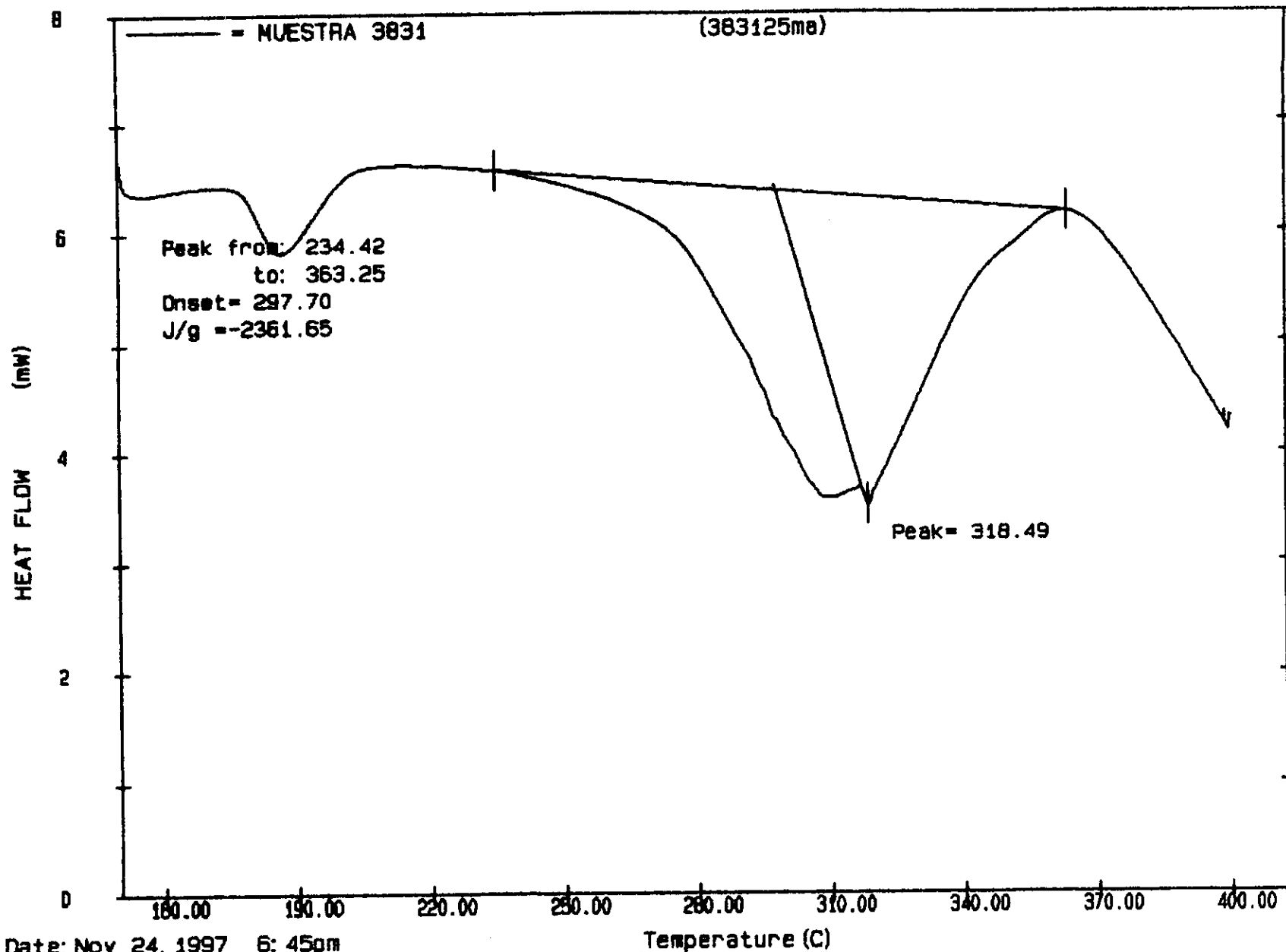
Date: Dec 02, 1997 08: 45am  
Scanning Rate: 5.0 C/min  
Sample Wt: 1.224 mg Path: a:\  
File 1: 108315MA AVM

PERKIN-ELMER DSC7



Date: Nov 25, 1997 08: 54am  
Scanning Rate: 2.5 C/min  
Sample Wt: 1.244 mg Path: a: \  
File 1: 343125MA AVM

PERKIN-ELMER DSC7

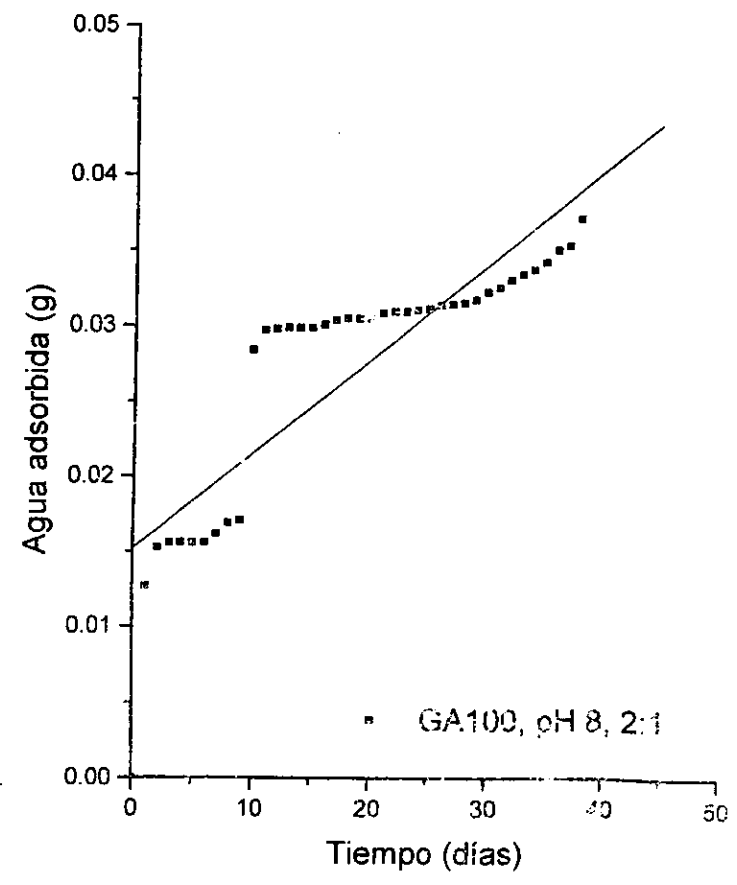
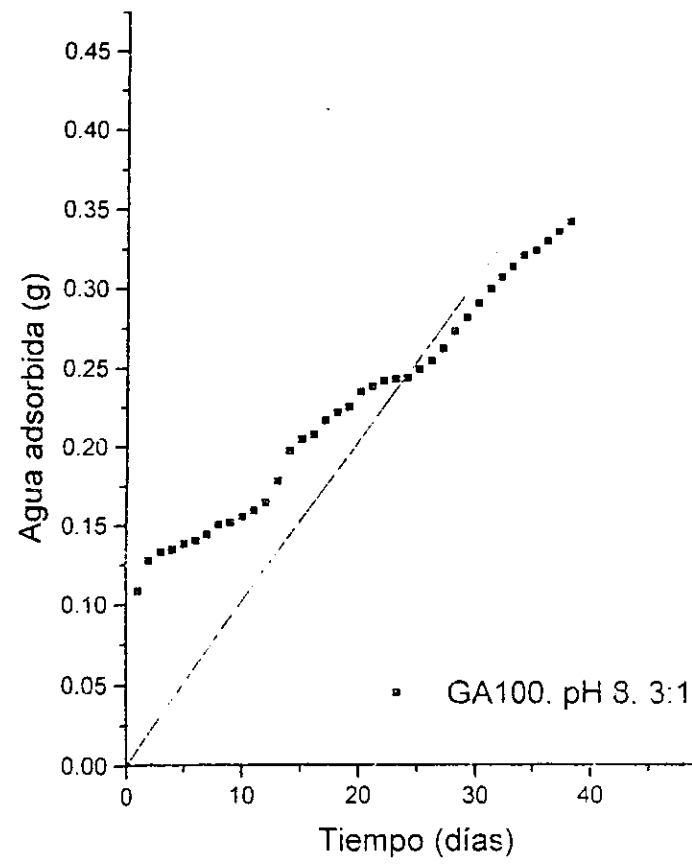
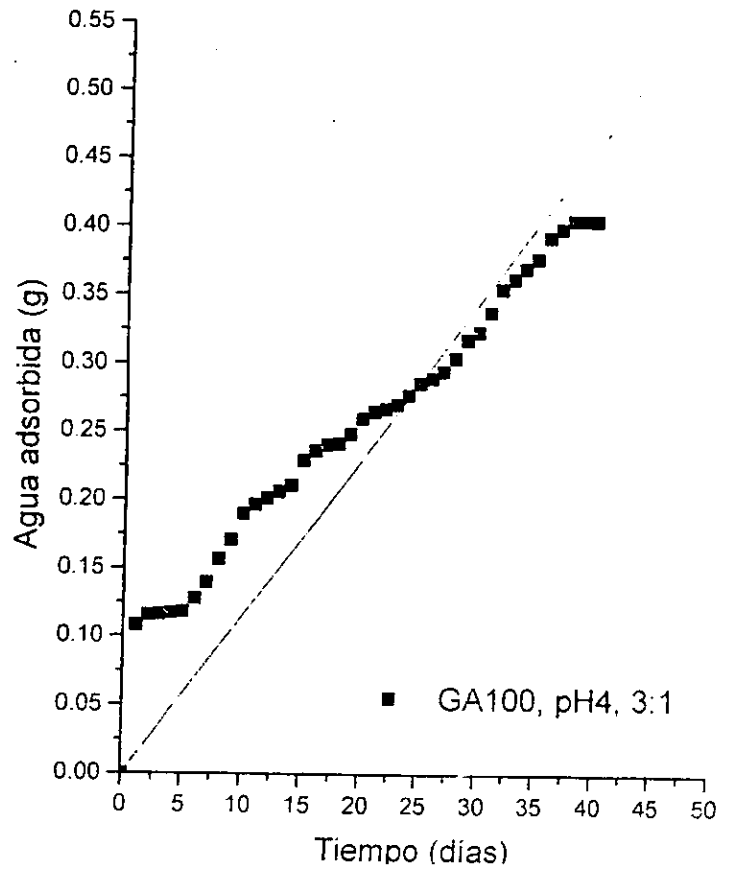
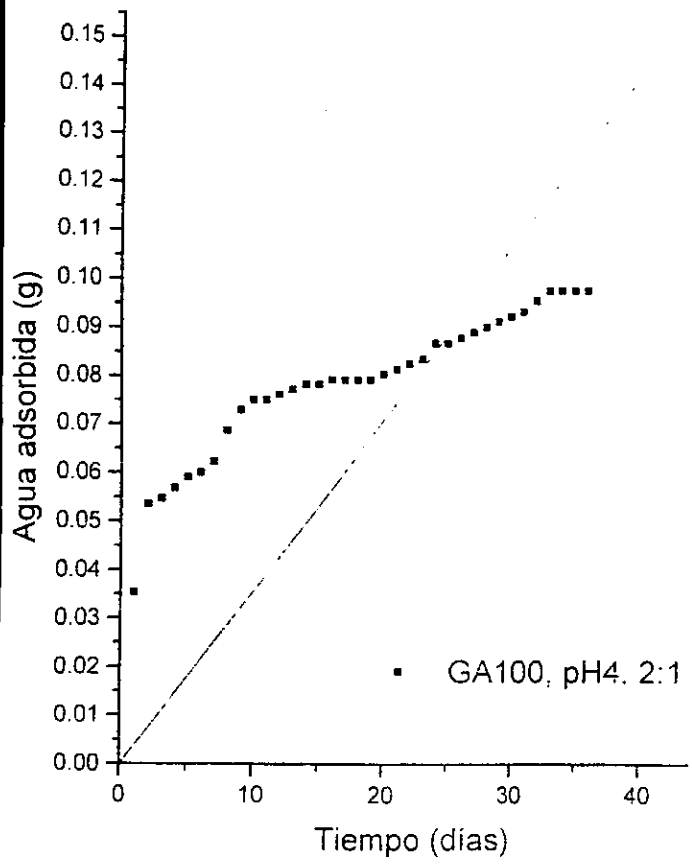


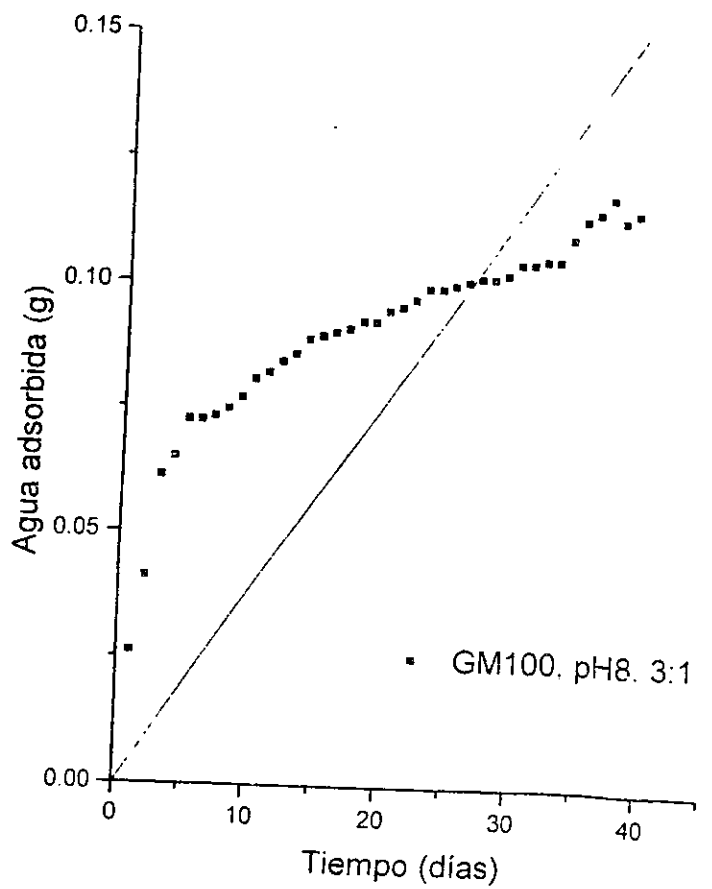
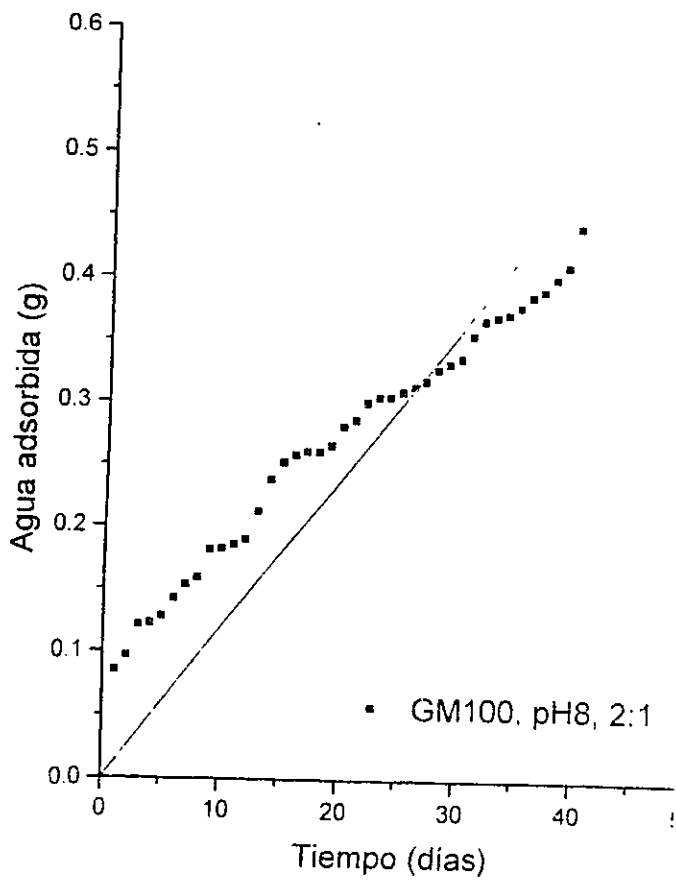
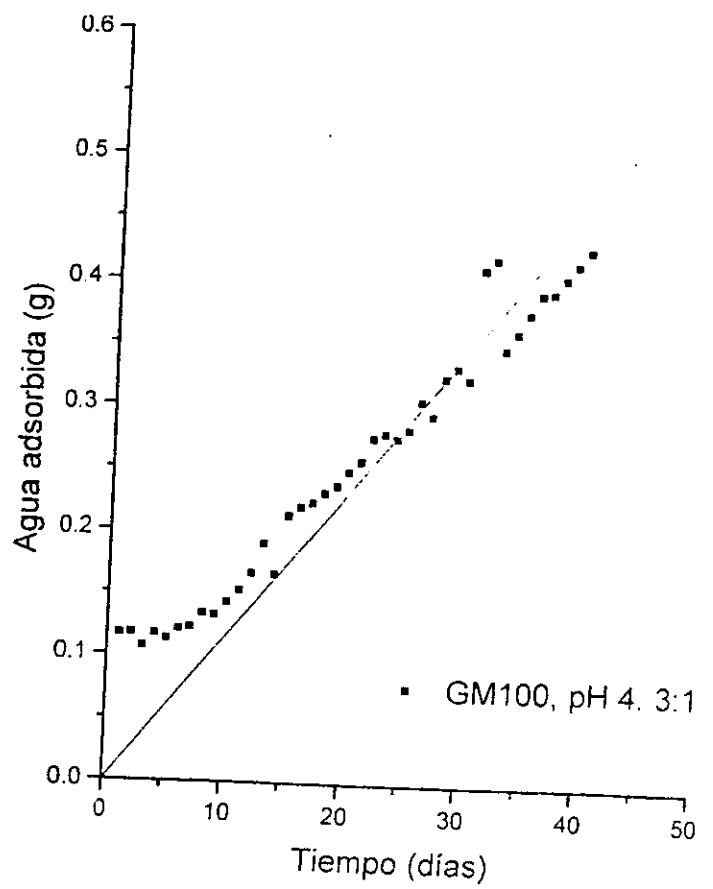
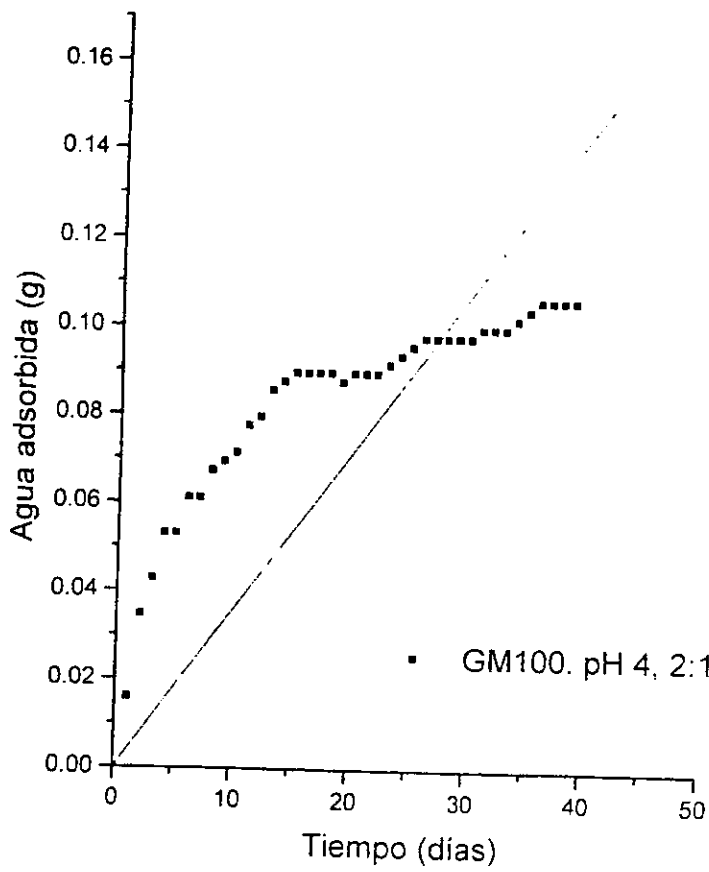
Date: Nov 24, 1997 6: 45pm  
Scanning Rate: 2.5 C/min  
Sample Wt: 1.363 mg Path: a:\  
File 1: 383125MA AVM

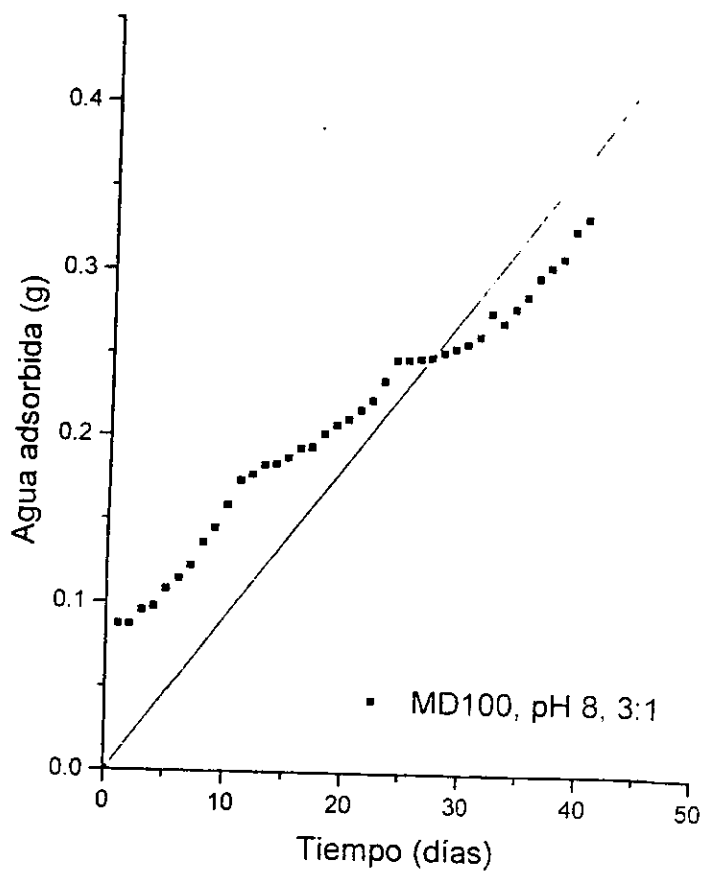
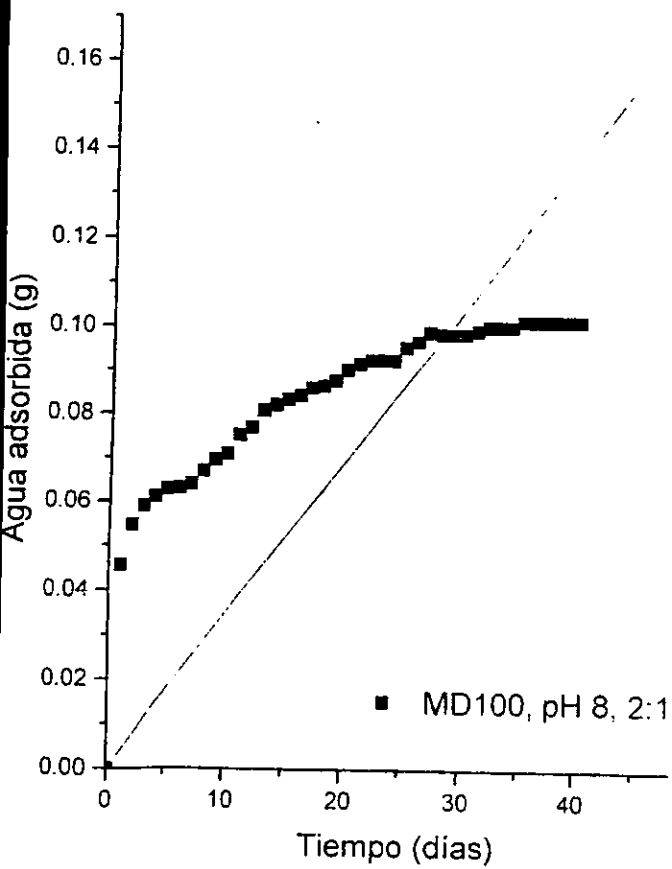
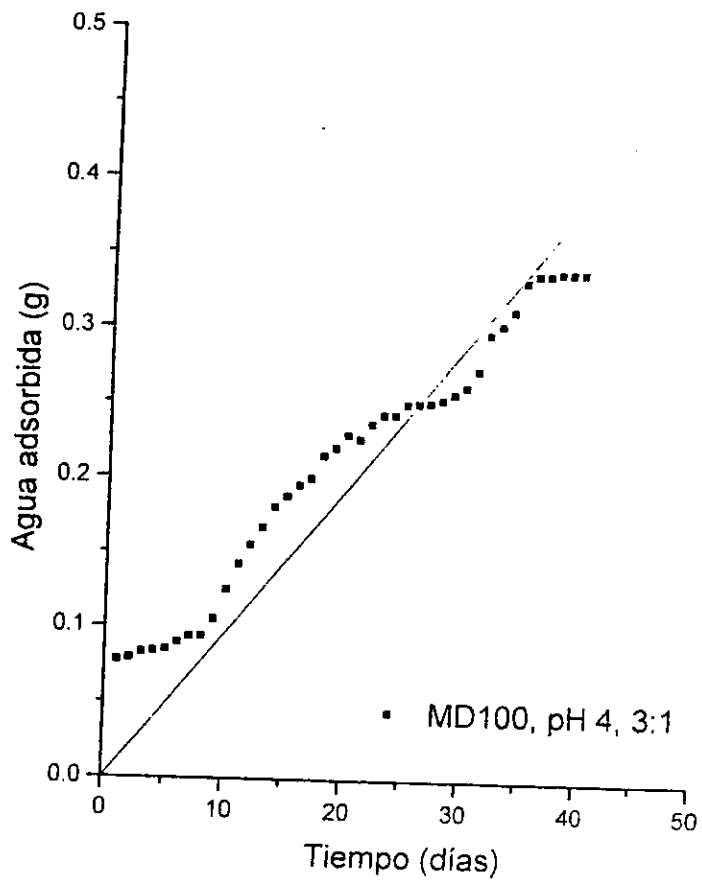
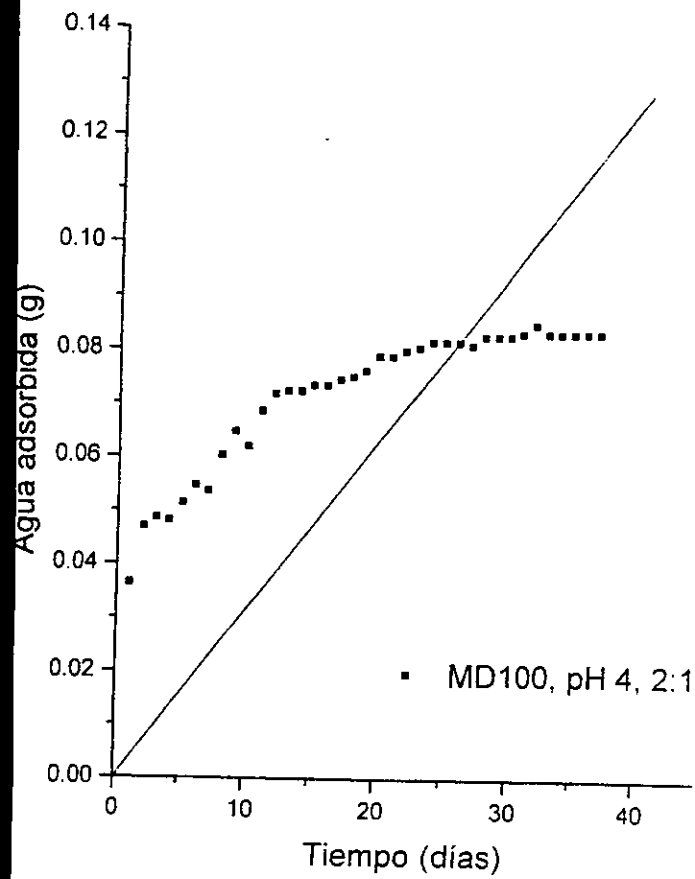
PERKIN-ELMER DSC7

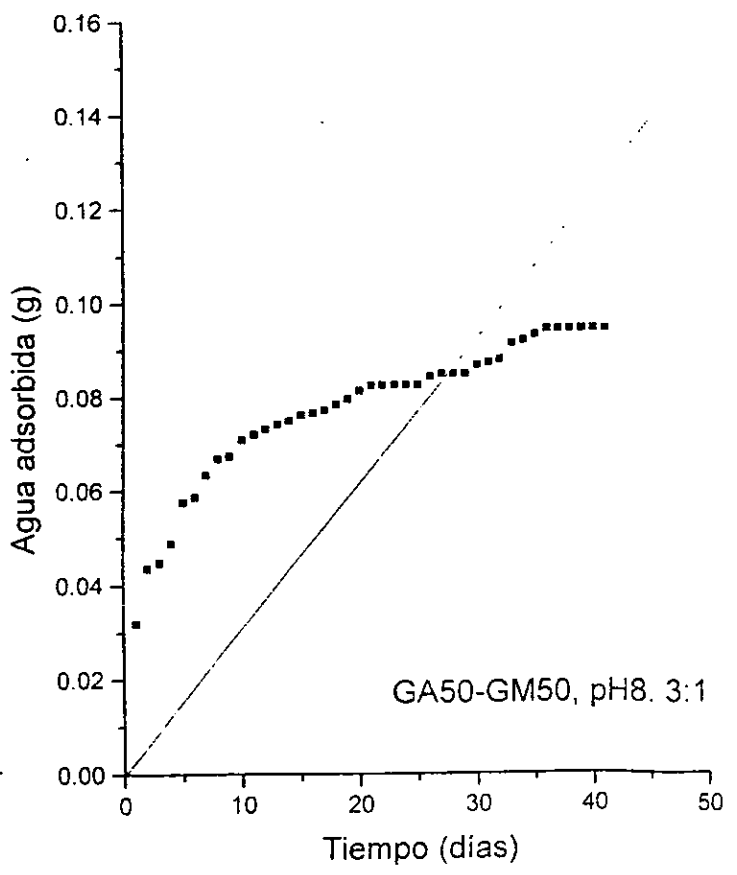
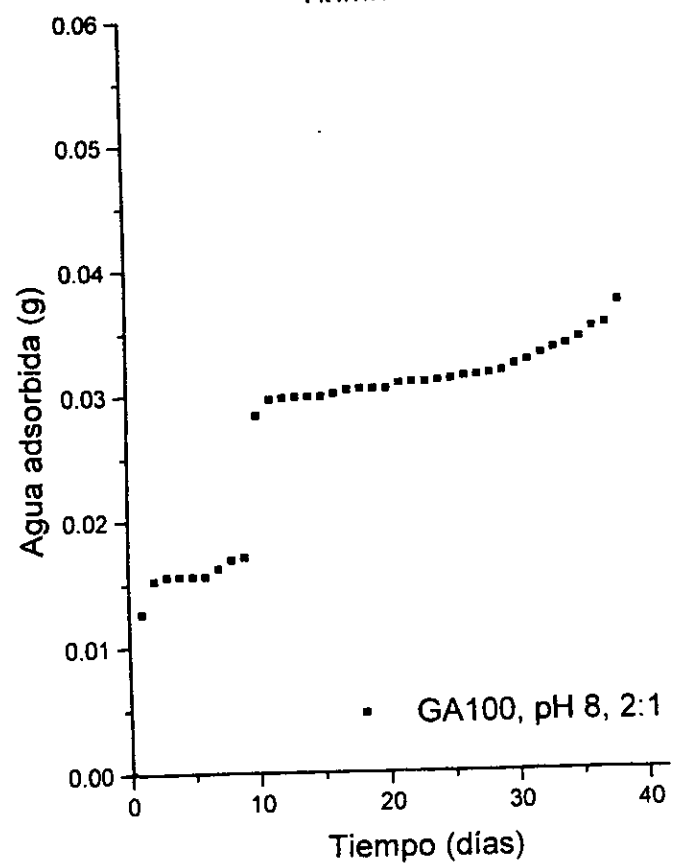
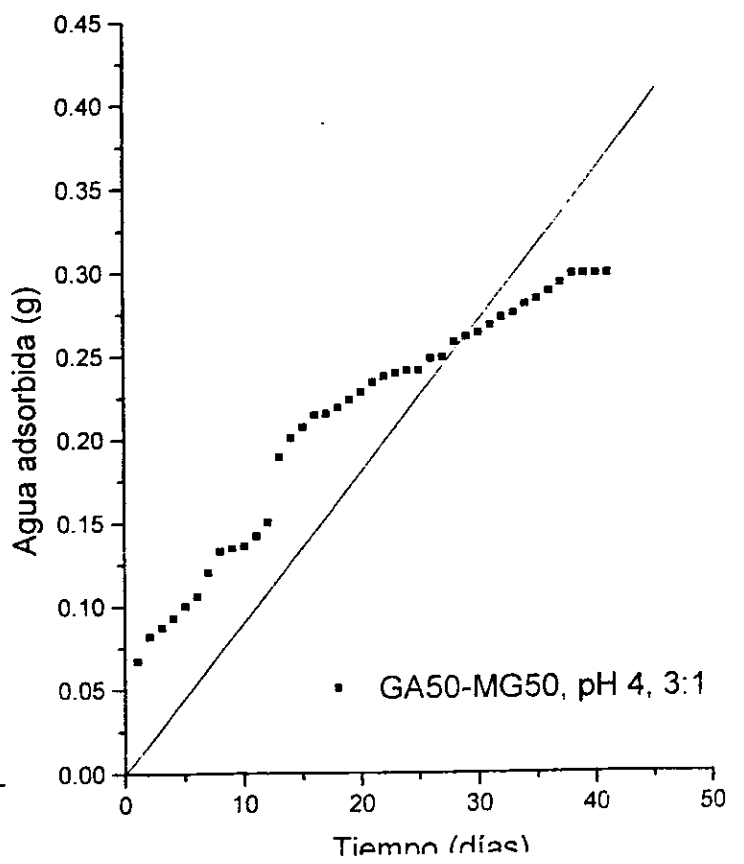
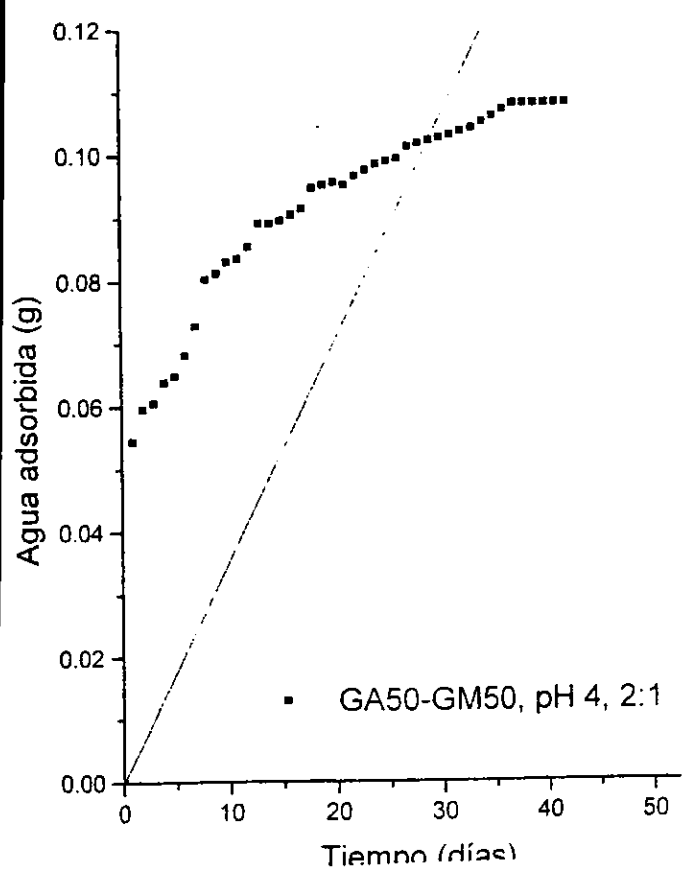
**APÉNDICE 8**  
**Gráficas de adsorción de agua**

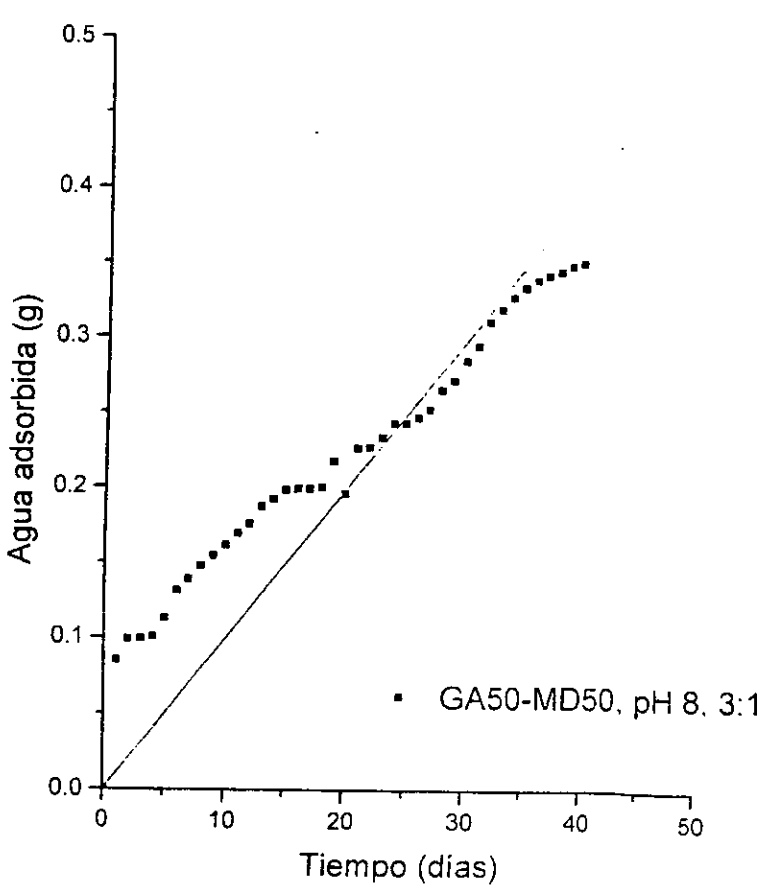
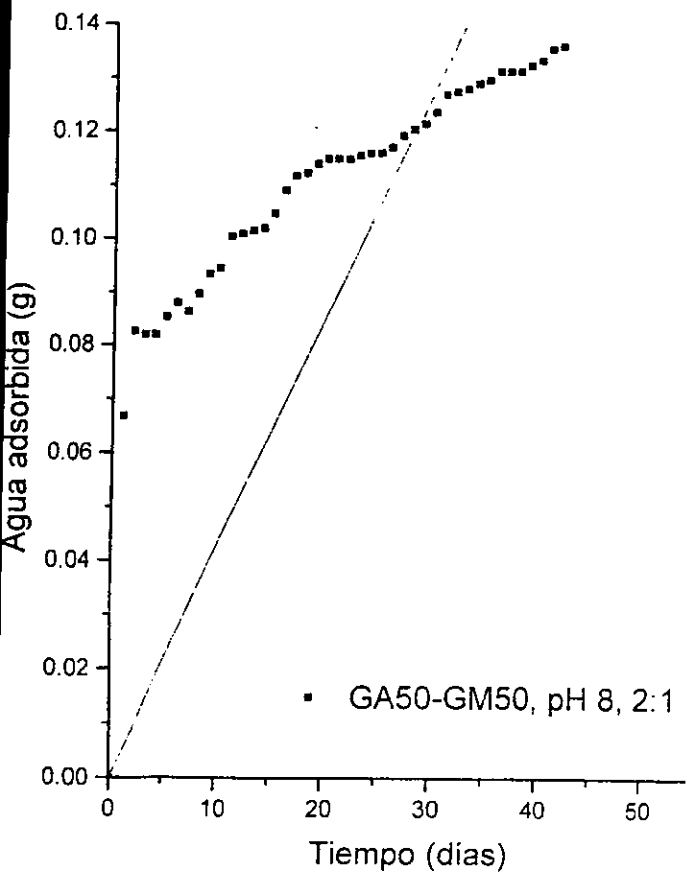
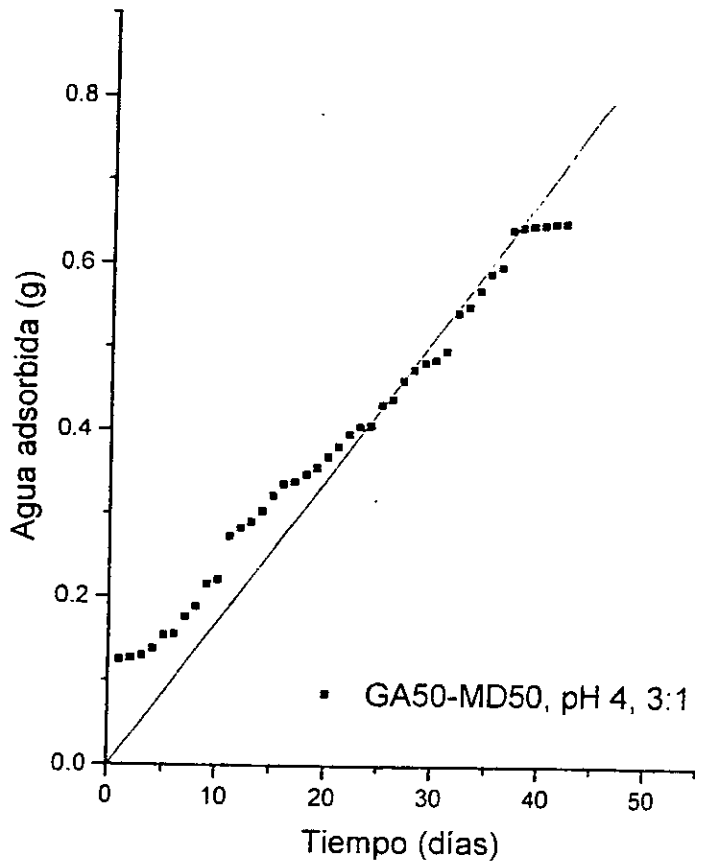
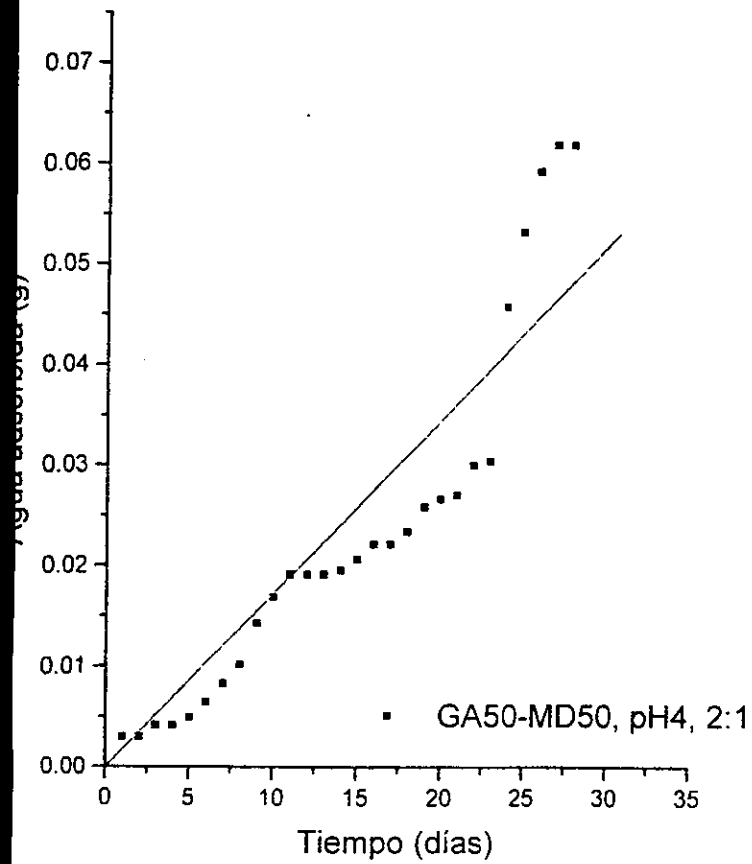


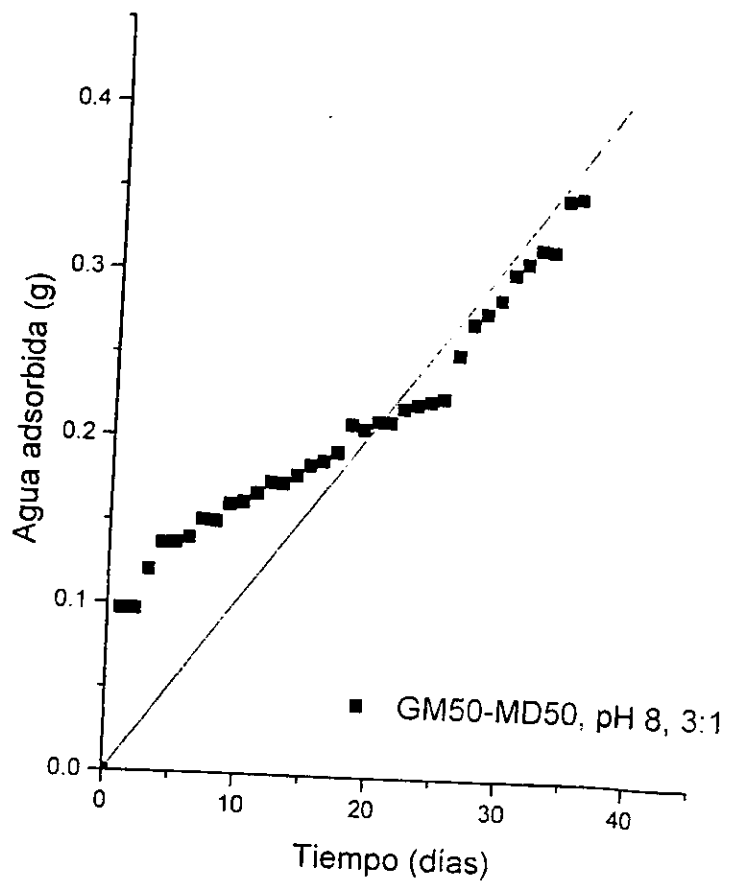
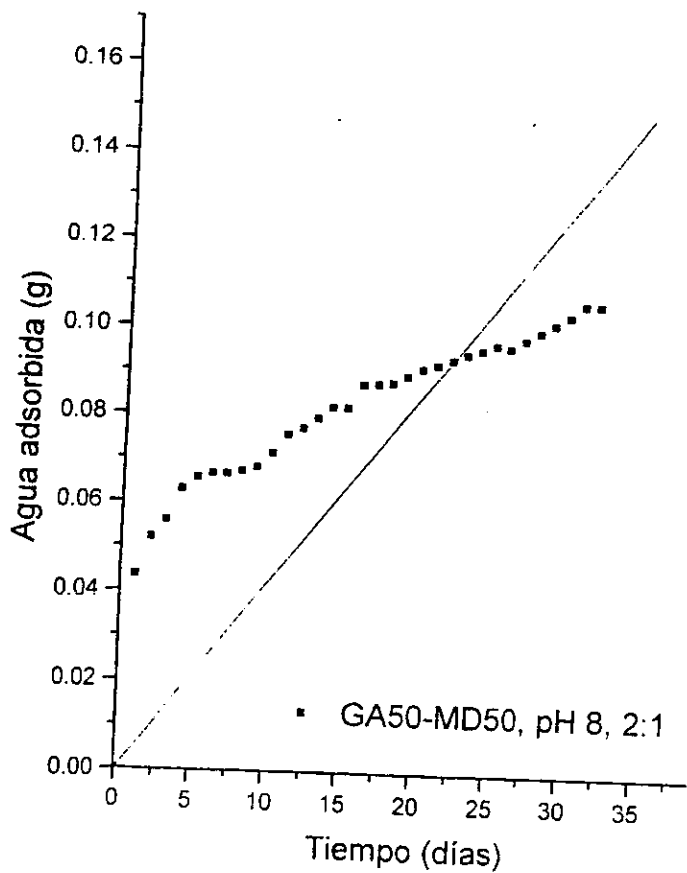
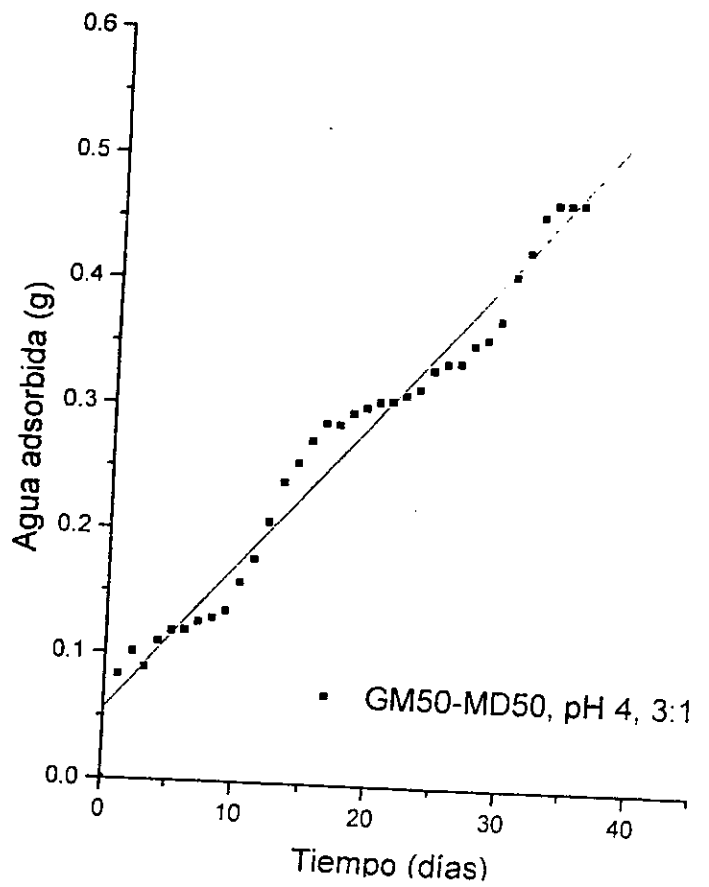
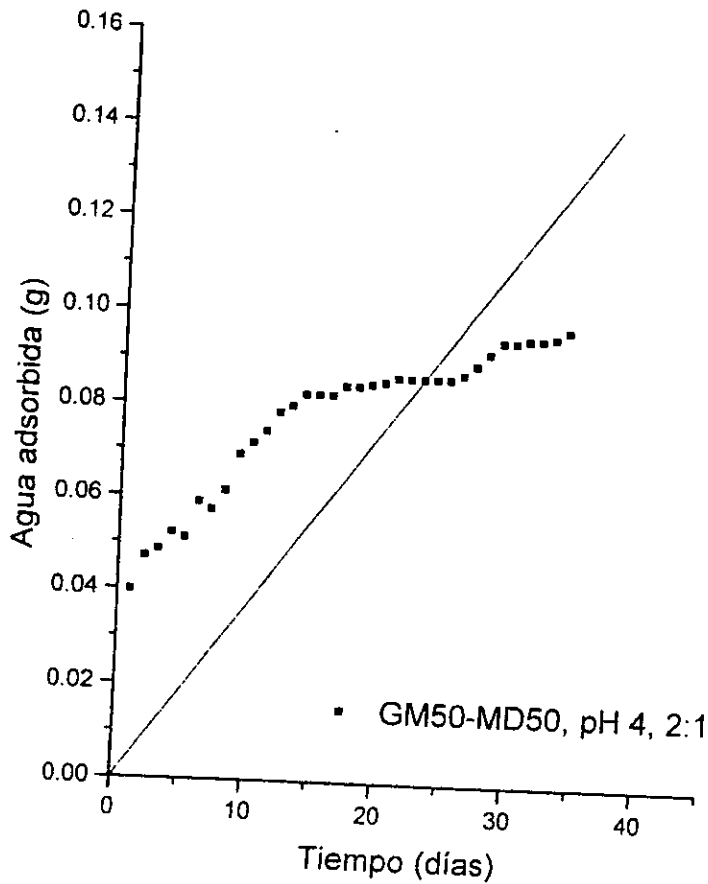


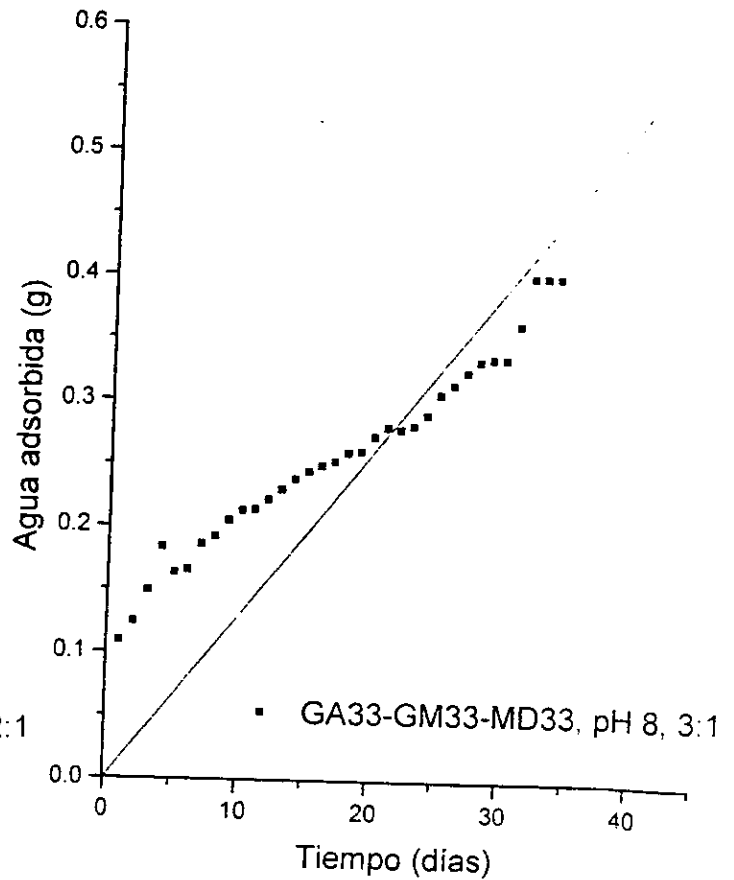
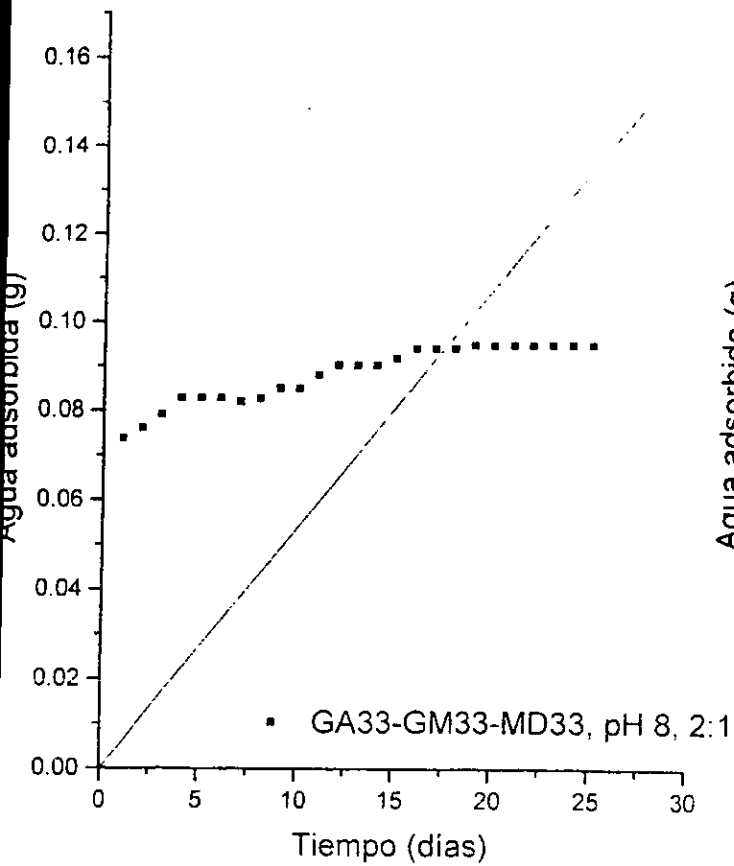
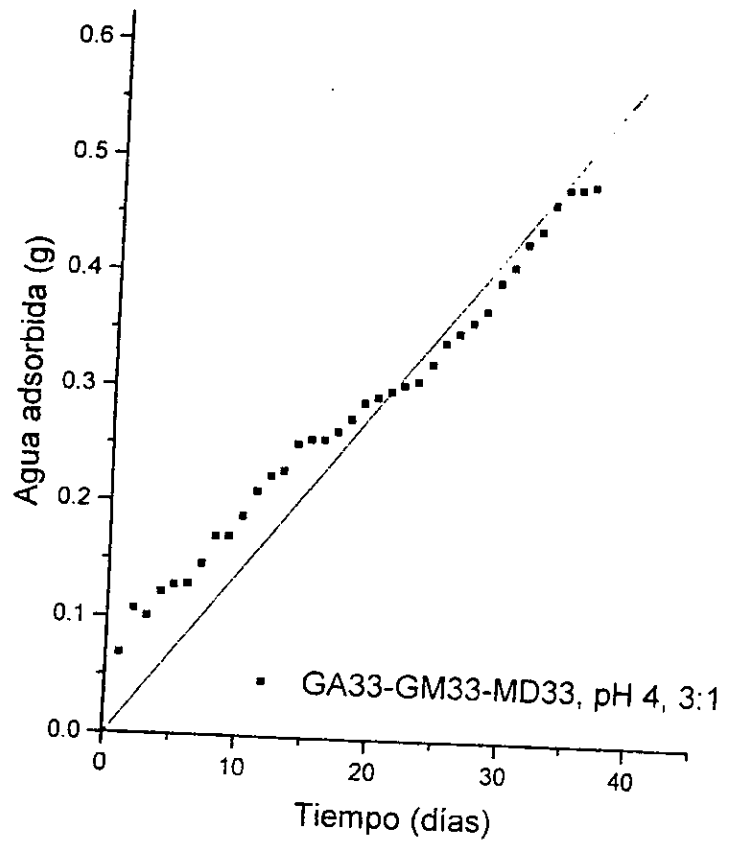
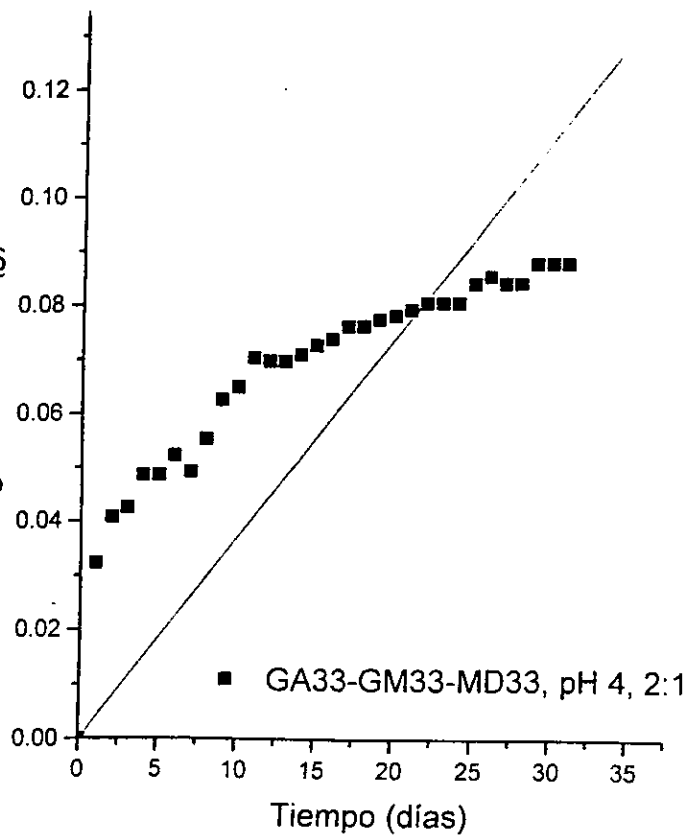


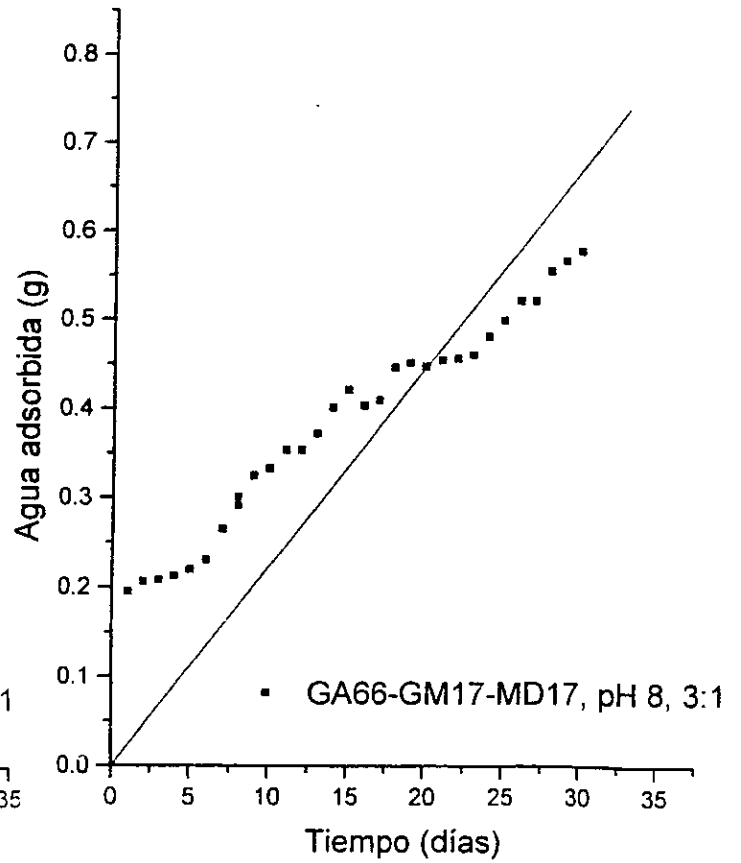
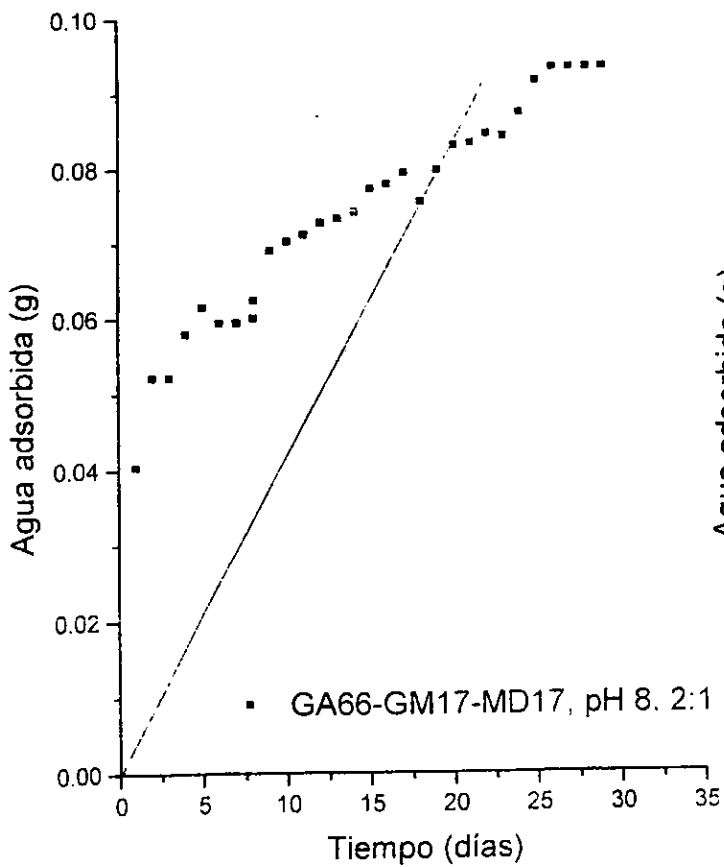
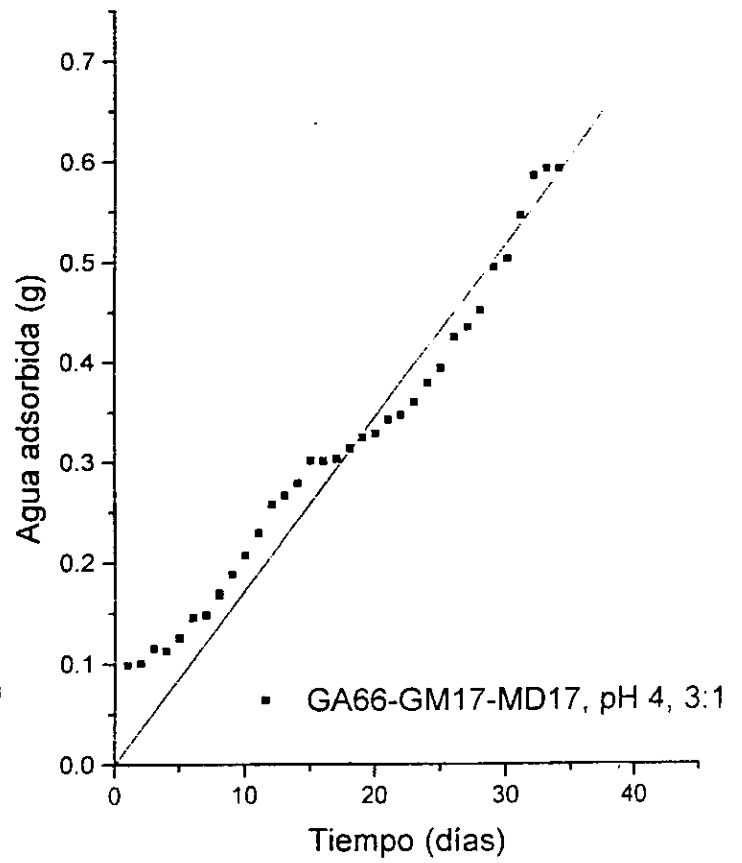
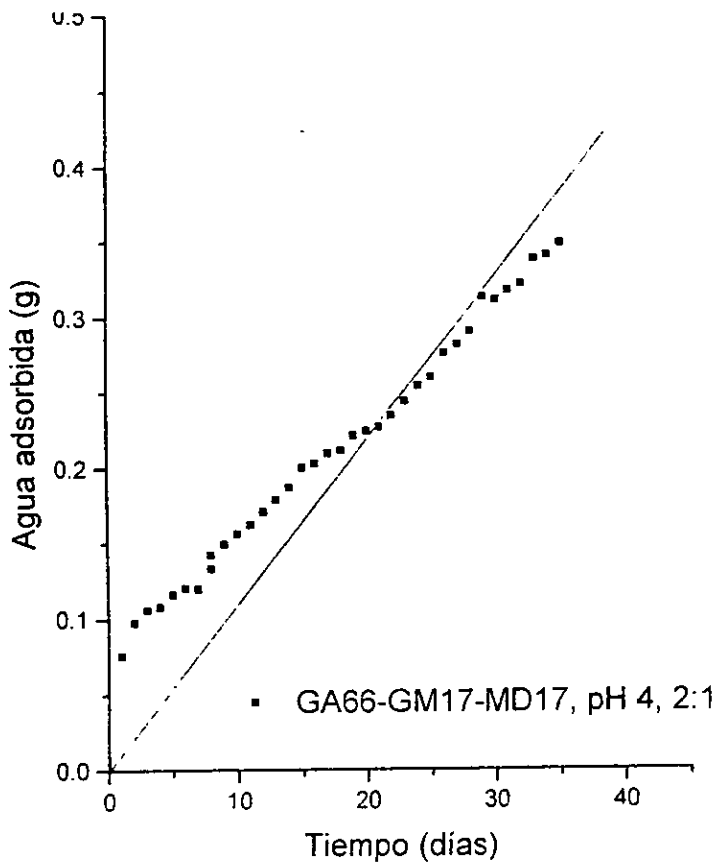




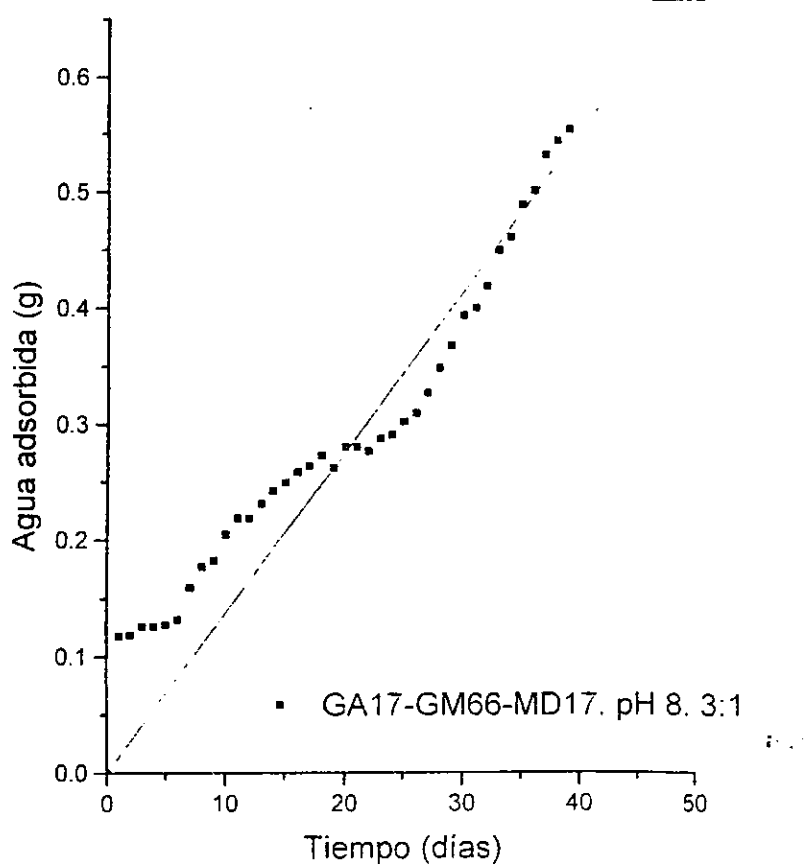
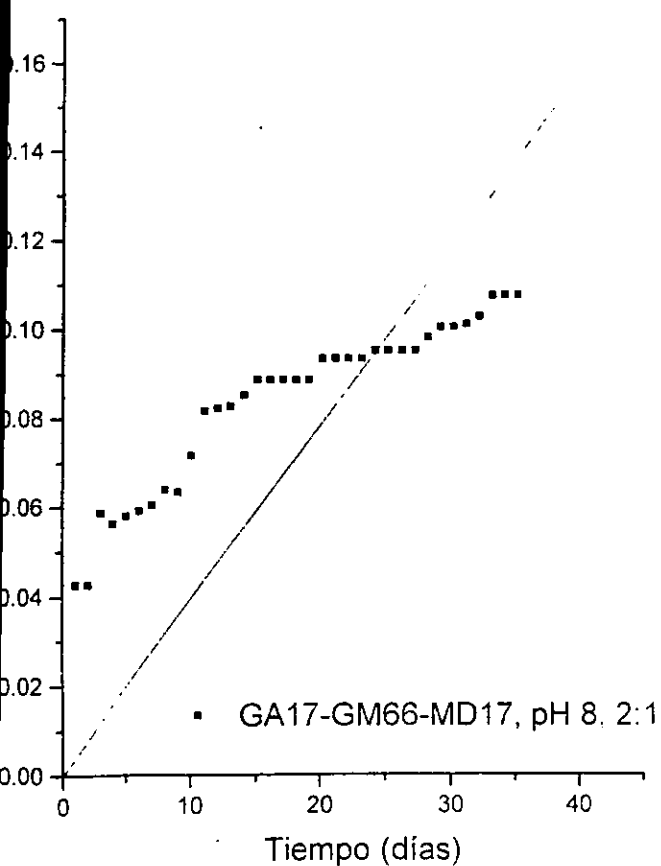
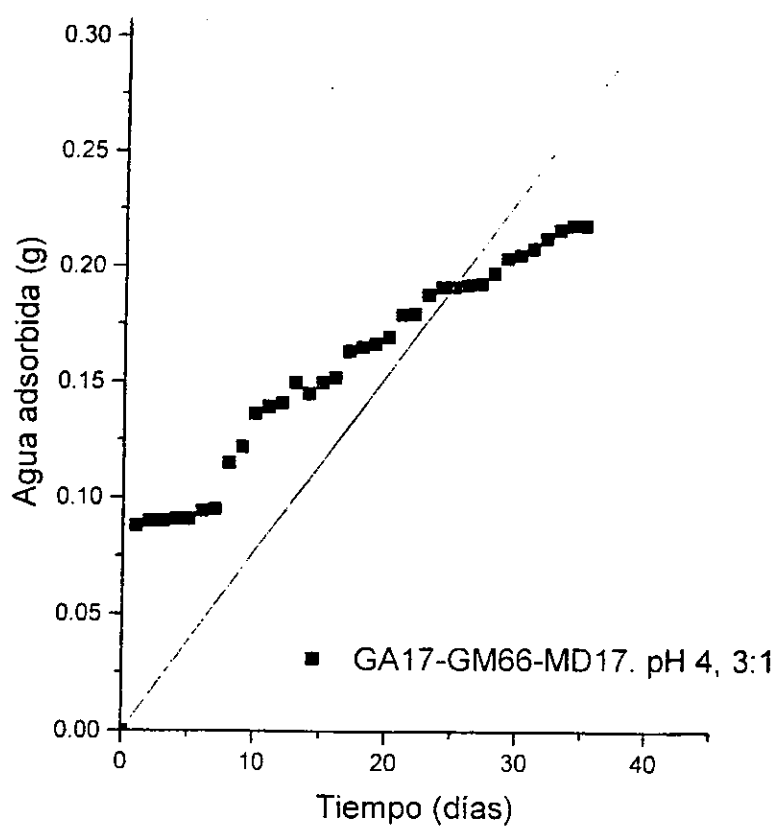
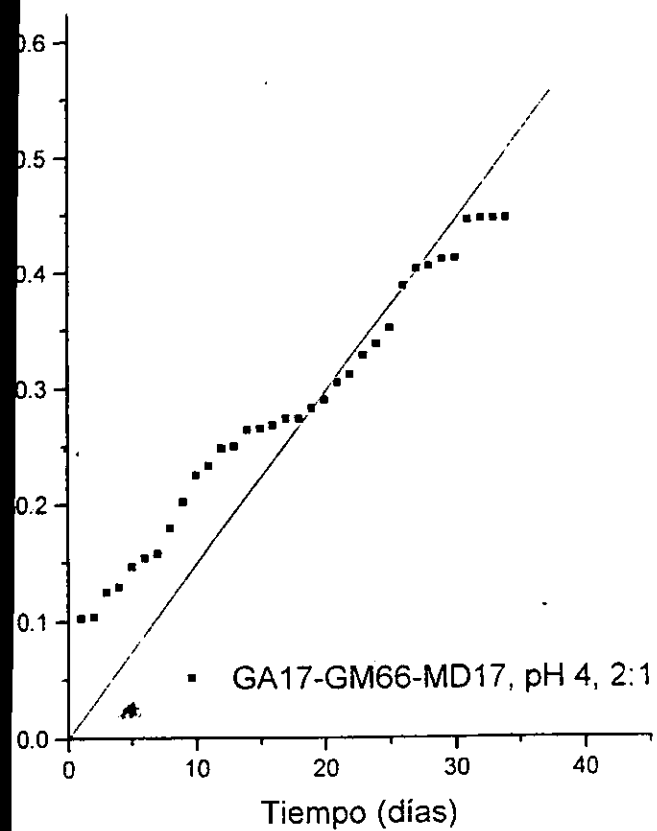


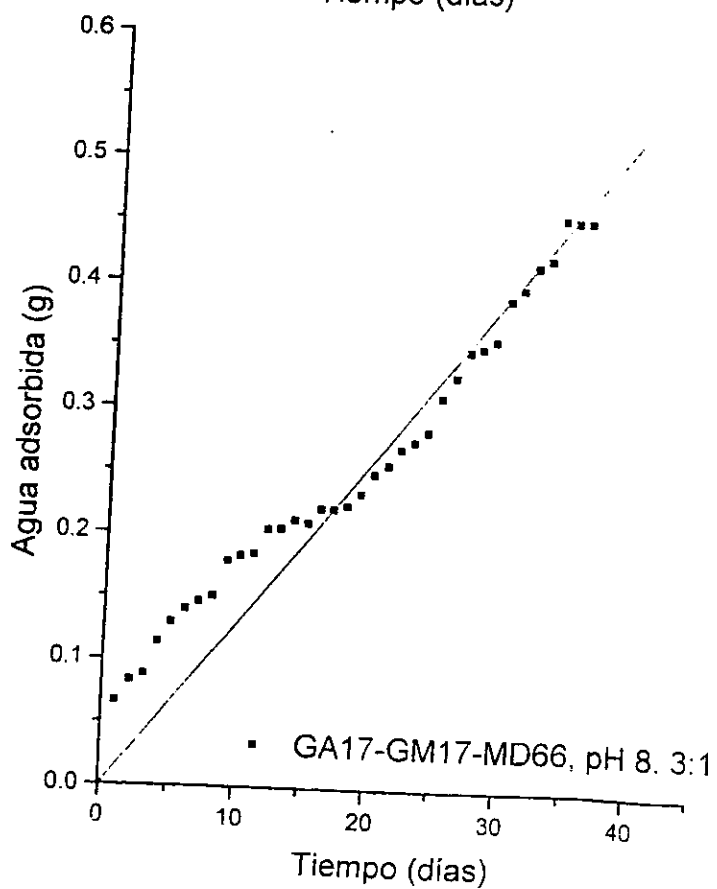
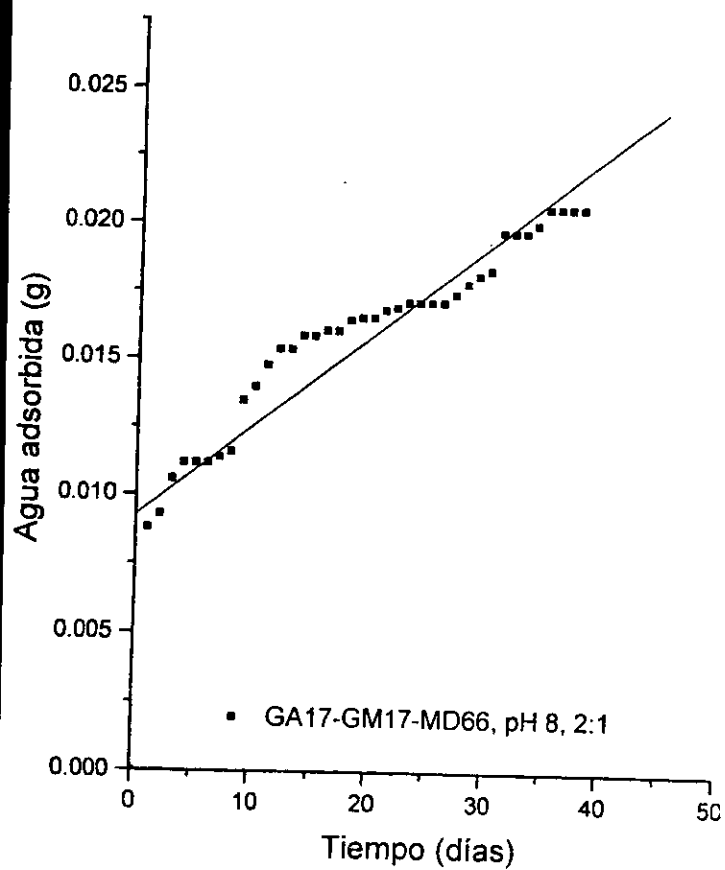
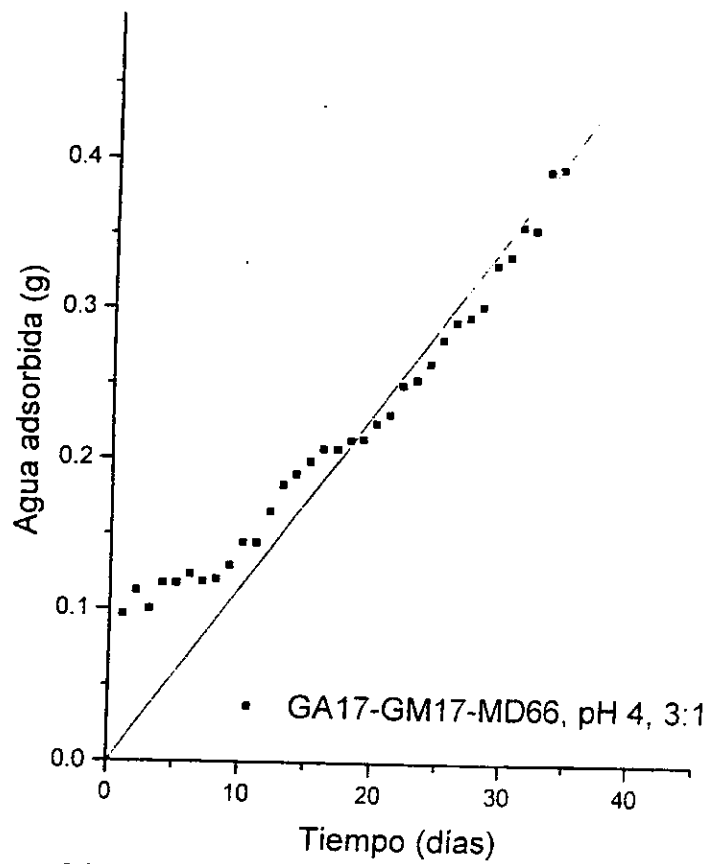
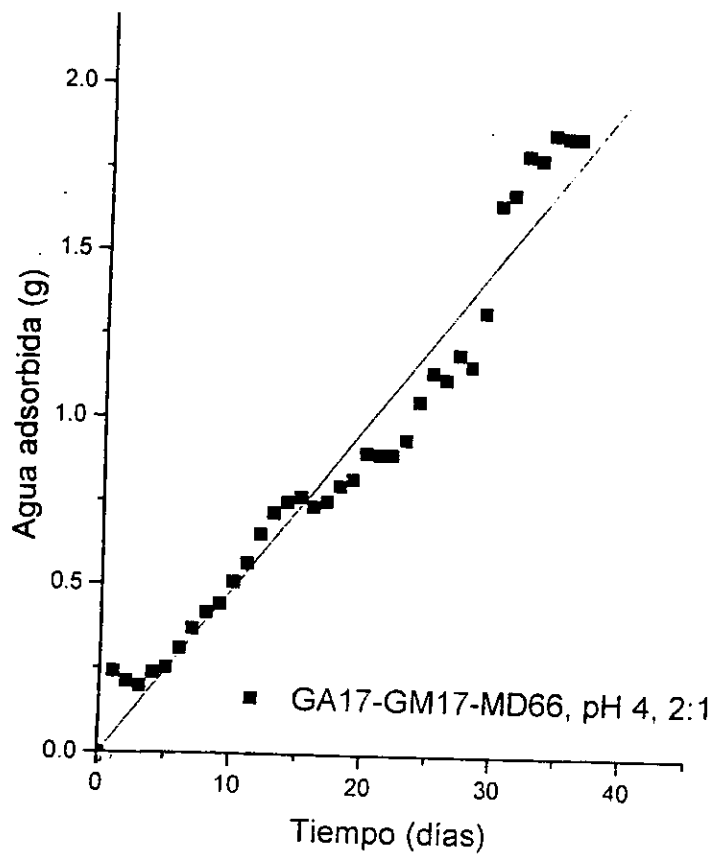




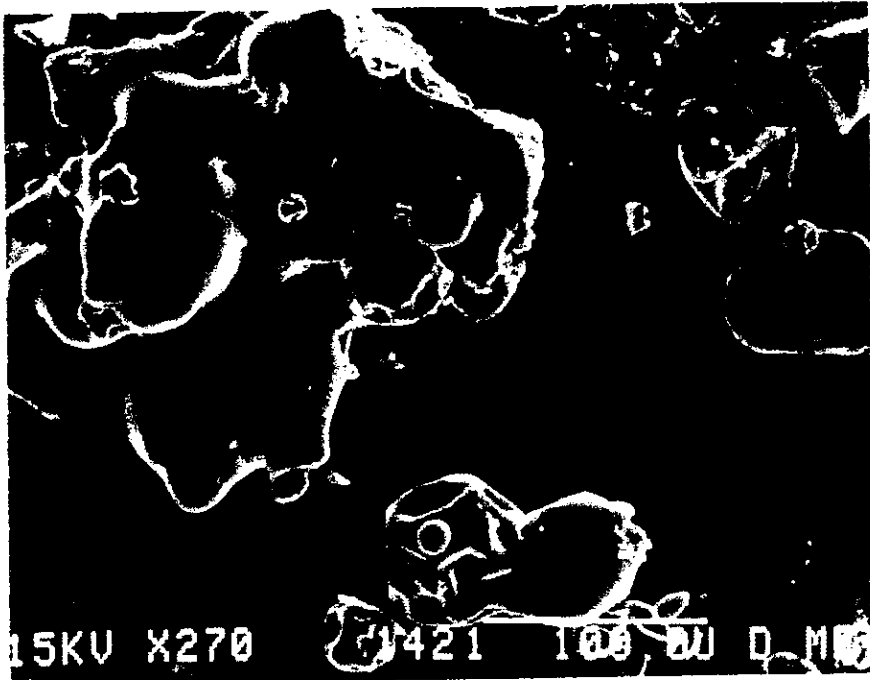




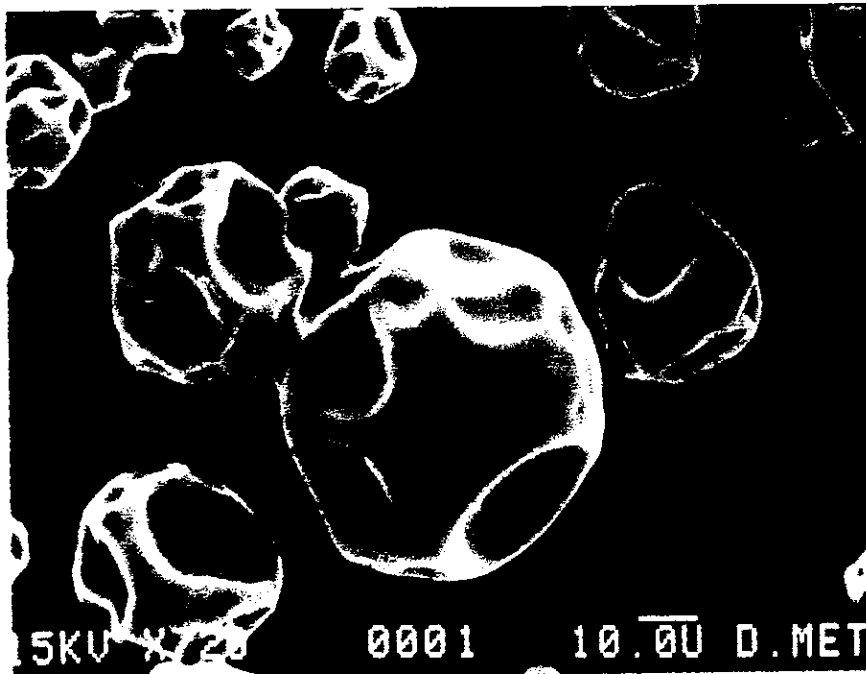




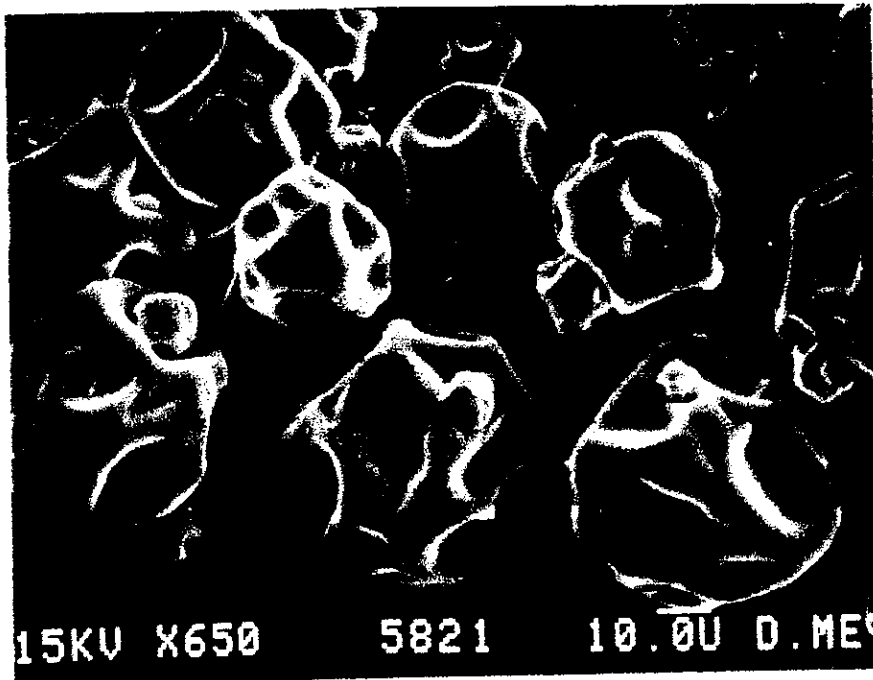
**APÉNDICE 9**  
**Micrografías de los tratamientos después de haber sometido a las  
microcápsulas a una atmósfera de 74% H.R.**



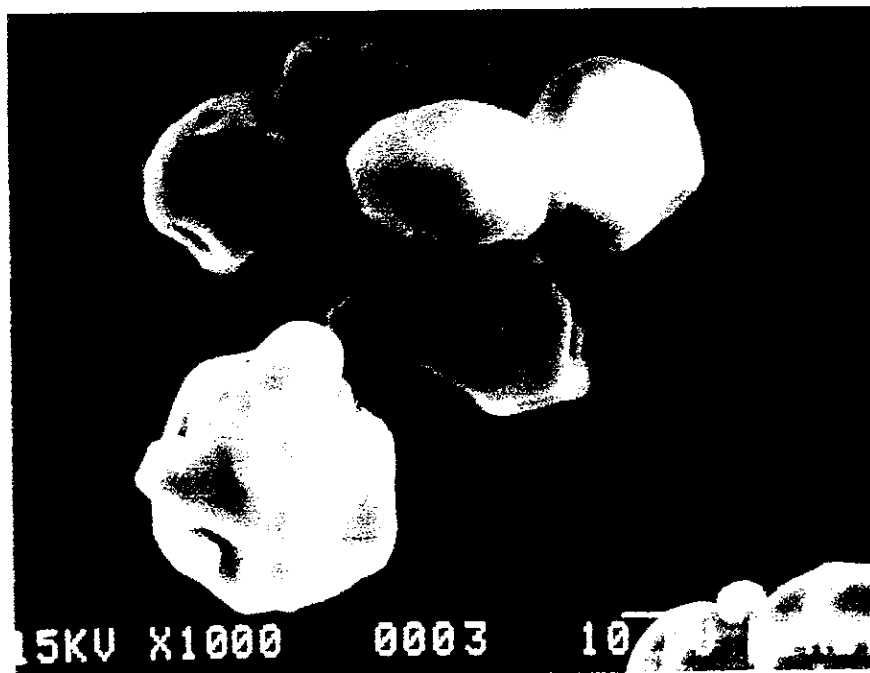
GA100 pH 4, rel 2:1  
74% humedad relativa



GA100 pH 4, rel 3:1  
74% humedad relativa



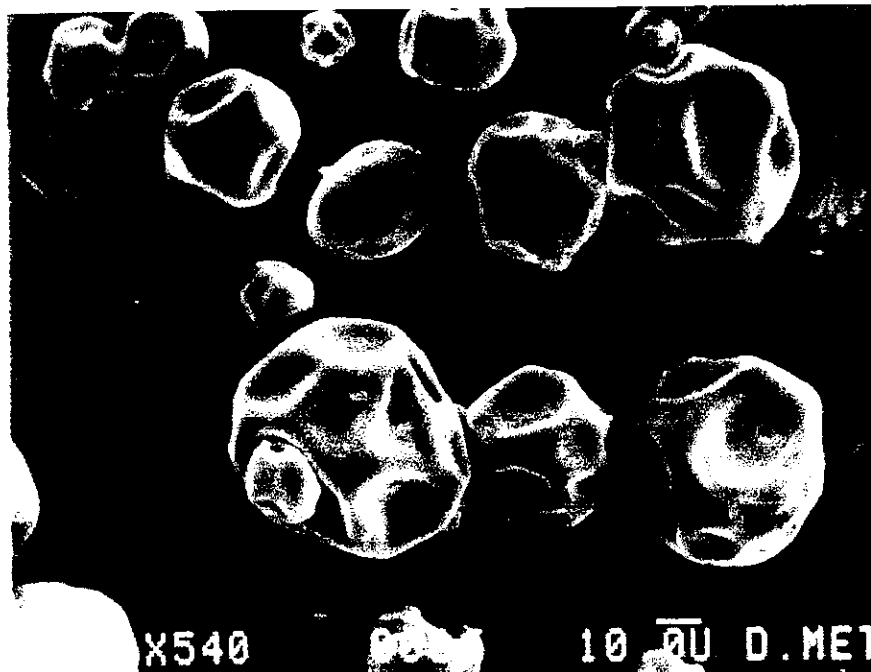
GA100 pH 8, rel 2:1  
74% humedad relativa



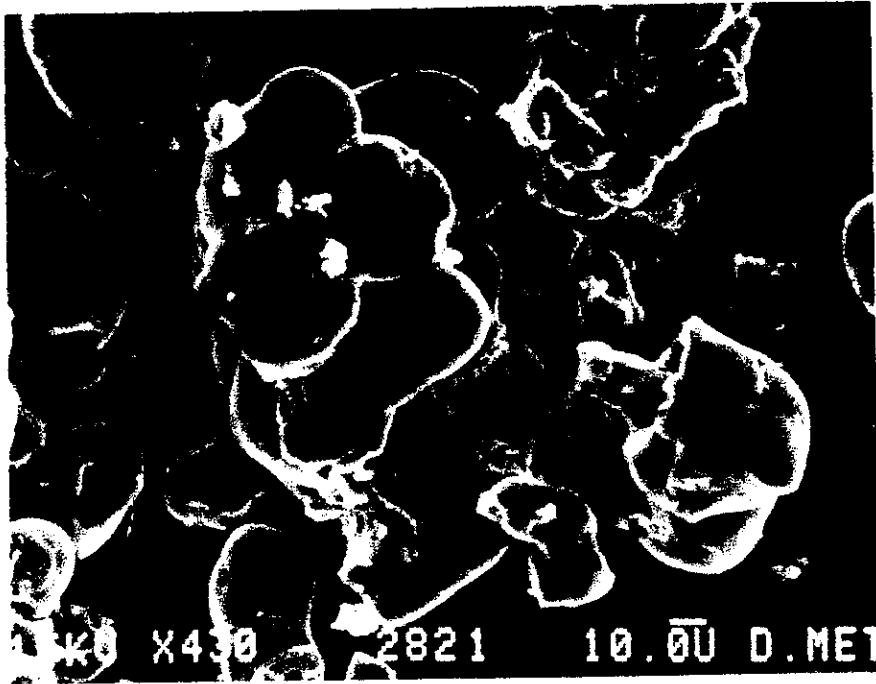
GA100 pH 8, rel 3:1  
74% humedad relativa



GM100 pH 4, rel 2:1  
74% humedad relativa



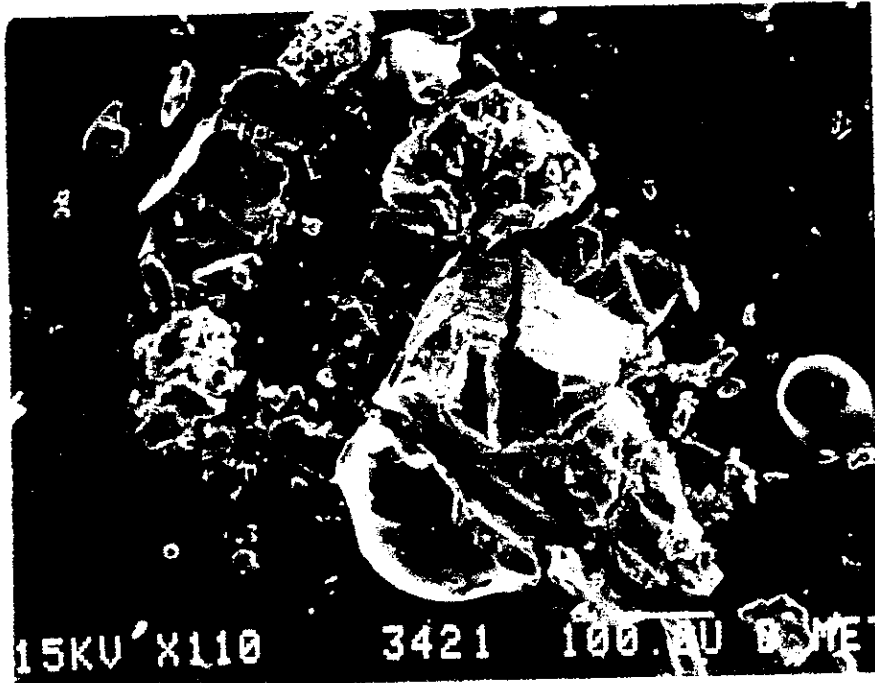
GM100 pH 4, rel 3:1  
74% humedad relativa



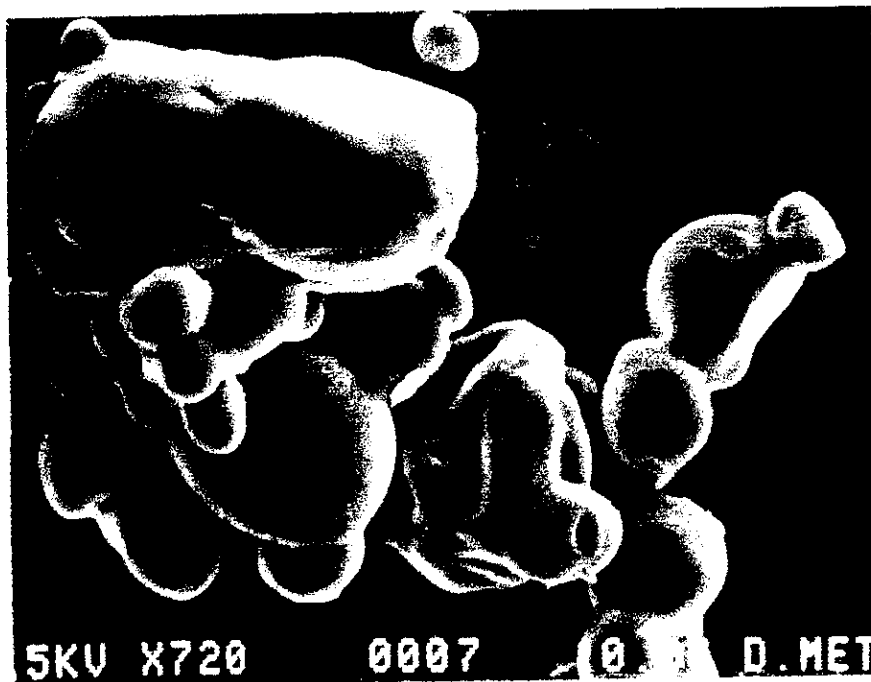
GM100 pH 8, rel 2:1  
74% humedad relativa



GM100 pH 8, rel 3:1  
74% humedad relativa



MD100 pH 4, rel 2:1  
74% humedad relativa



MD100 pH 4, rel 3:1  
74% humedad relativa





MD100 pH 8, rel 2:1  
74% humedad relativa



MD100 pH 8, rel 3:1  
74% humedad relativa



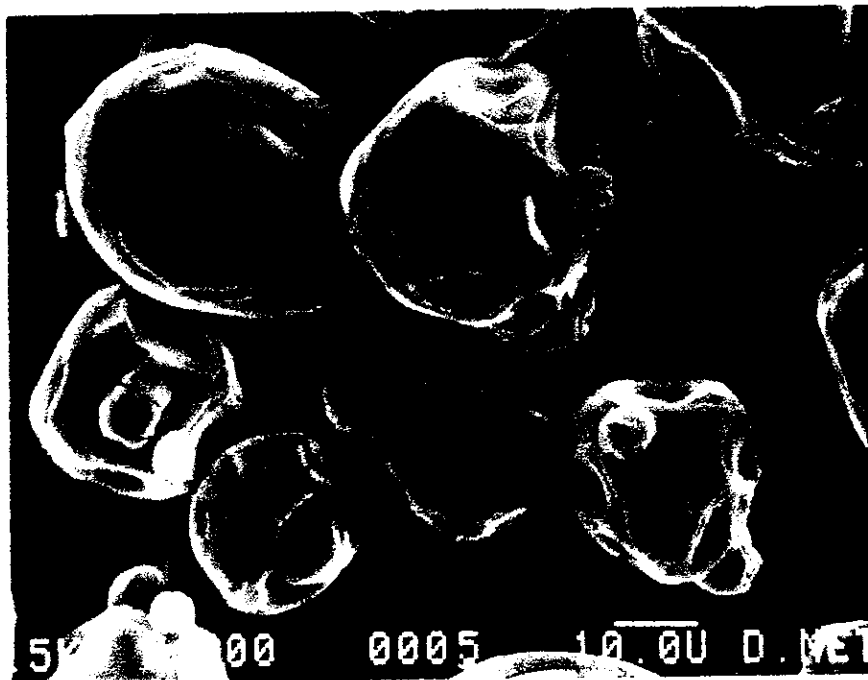
GA50-GM50 pH 4, rel 2:1  
74% humedad relativa



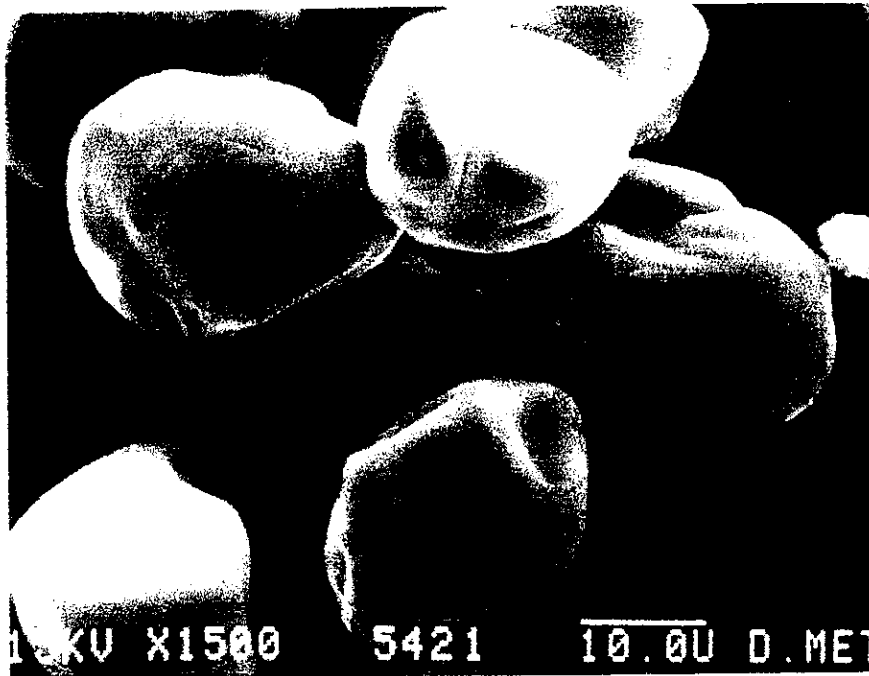
GA50-GM50 pH 4, rel 3:1  
74% humedad relativa



GA50-GM50 pH 8, rel 2:1  
74% humedad relativa



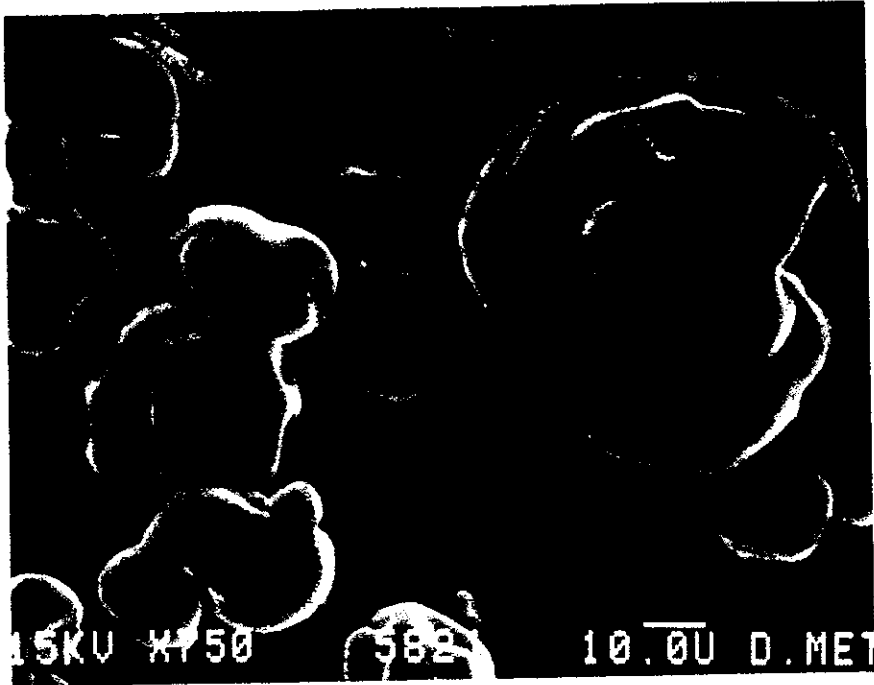
GA50-GM50-pH 8, rel 3:1  
74% humedad relativa



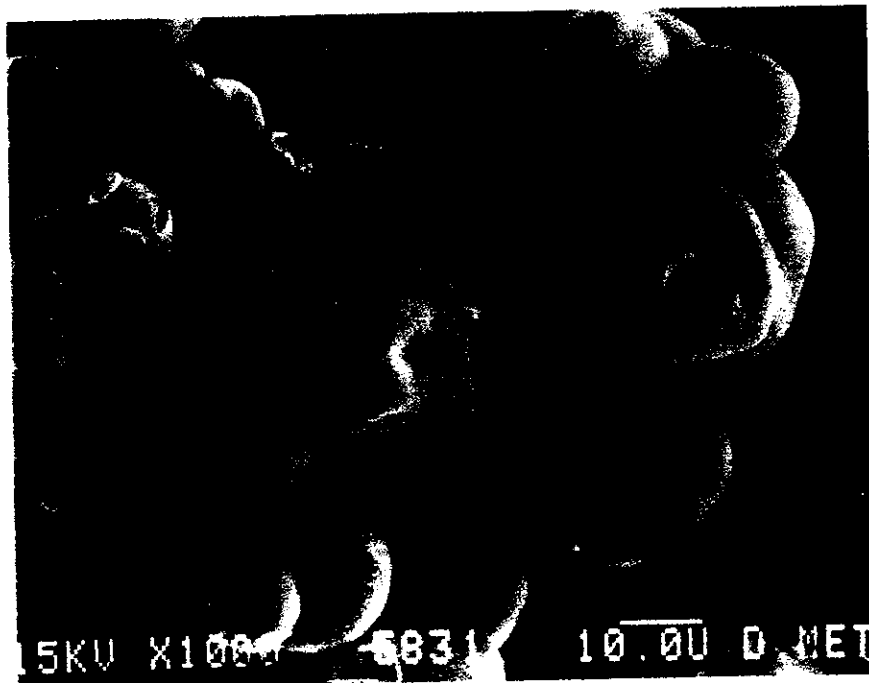
GA50-MD50 pH 4, rel 2:1  
74% humedad relativa



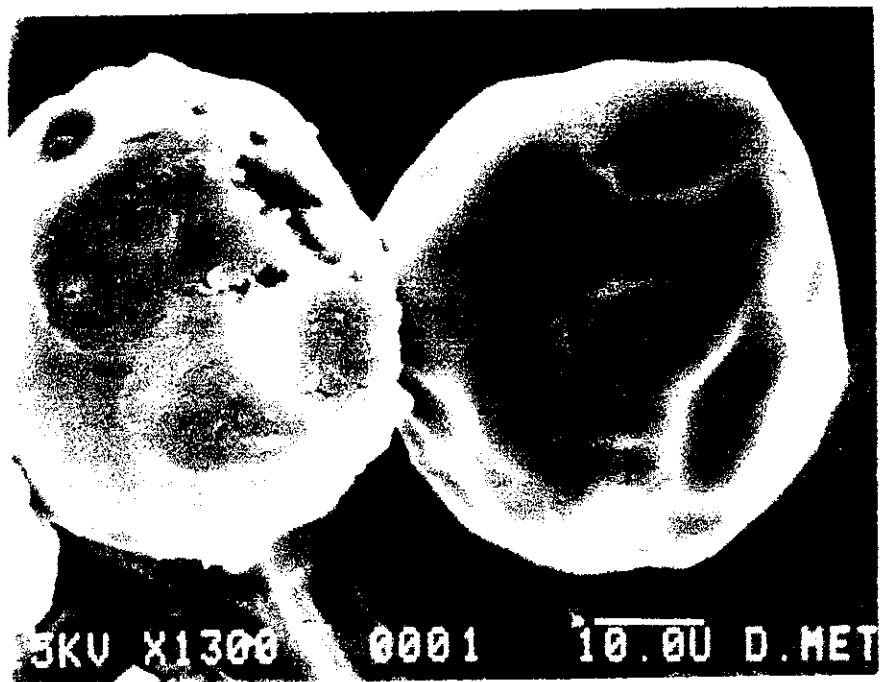
GA50-MD50 pH 4, rel 3:1  
74% humedad relativa



GA50-MD50 pH 8, rel 2:1  
74% humedad relativa



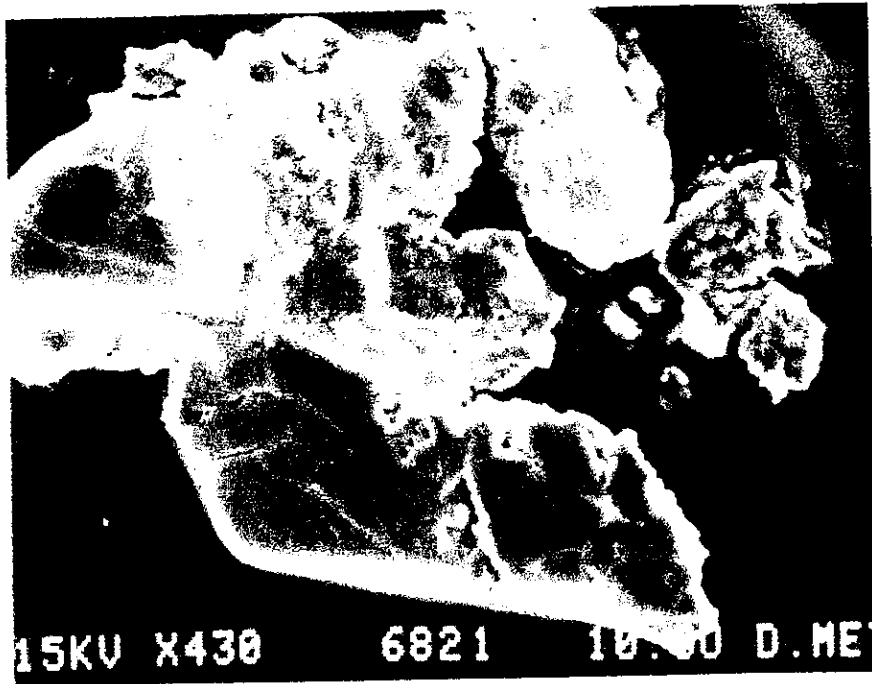
GA50-MD50 pH 8, rel 3:1  
74% humedad relativa



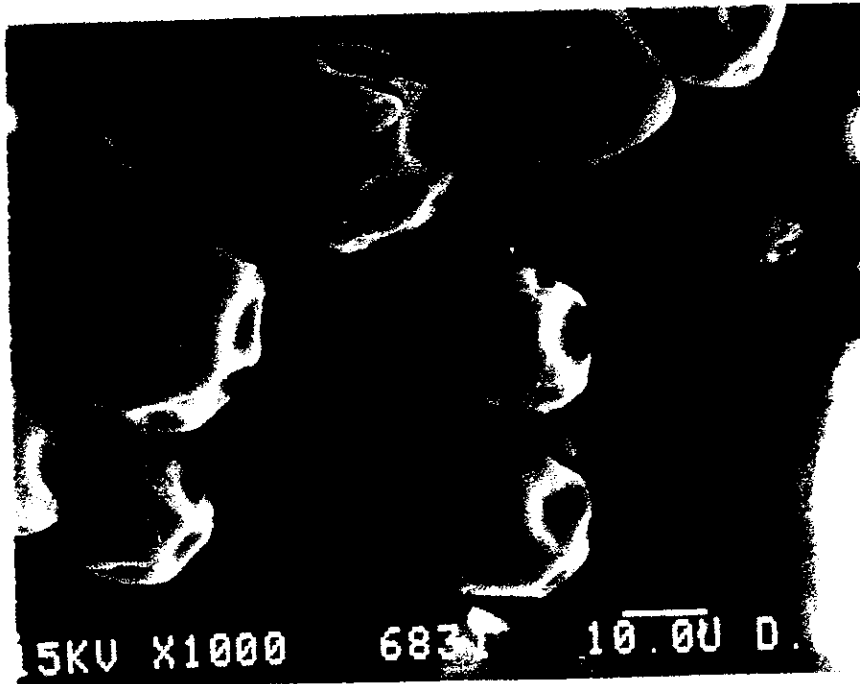
GM50-MD50 pH 4, rel 2:1  
74% humedad relativa



GM50-MD50 pH 4, rel 2:1  
74% humedad relativa



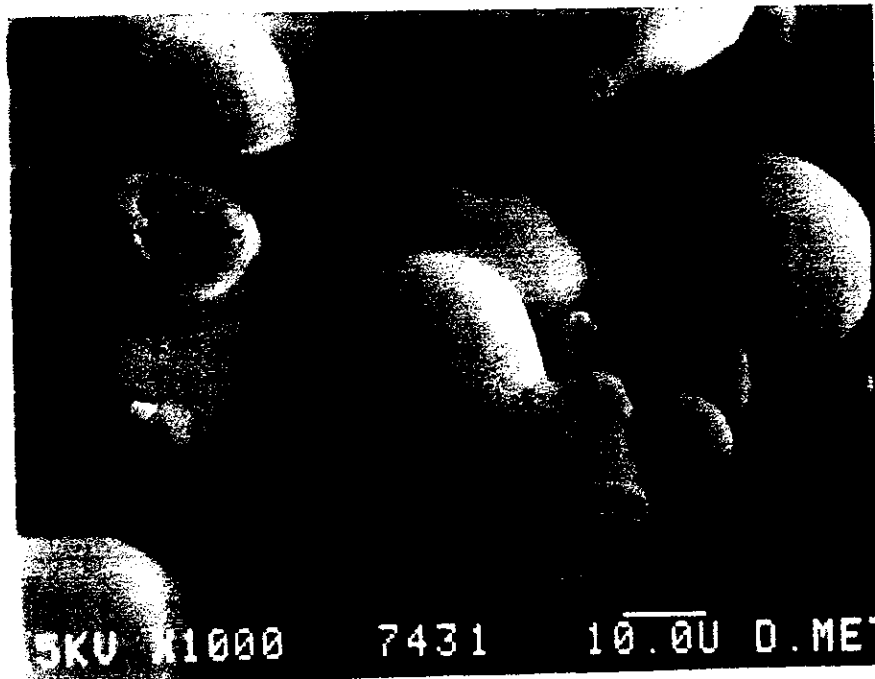
GM50-MD50 pH 8, rel 2:1  
74% humedad relativa



GM50-MD50 pH 8, rel 3:1  
74% humedad relativa



GA33-GM33-MD33 pH 4, rel 2:1  
74% humedad relativa

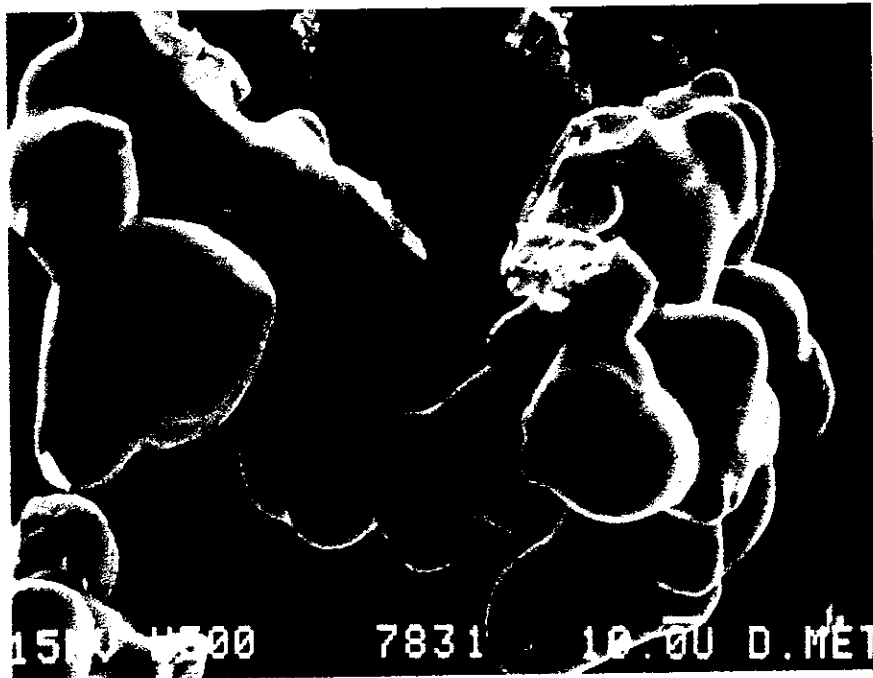


GA33-GM33-MD33 pH 4, rel 3:1  
74% humedad relativa

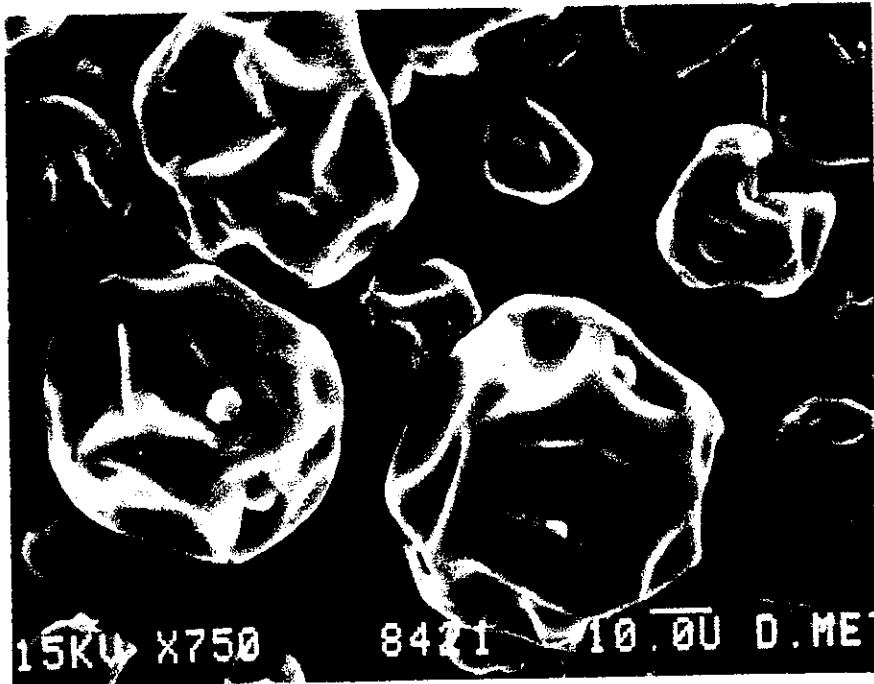




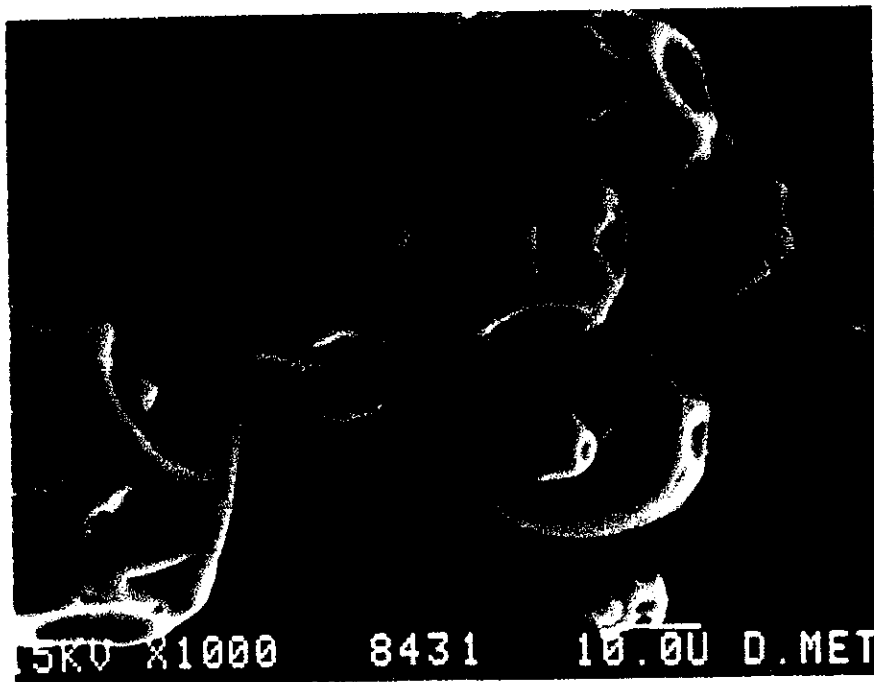
GA33-GM33-MD33 pH 8, rel 2:1  
74% humedad relativa



GA33-GM33-MD33 pH 8, rel 3:1  
74% humedad relativa



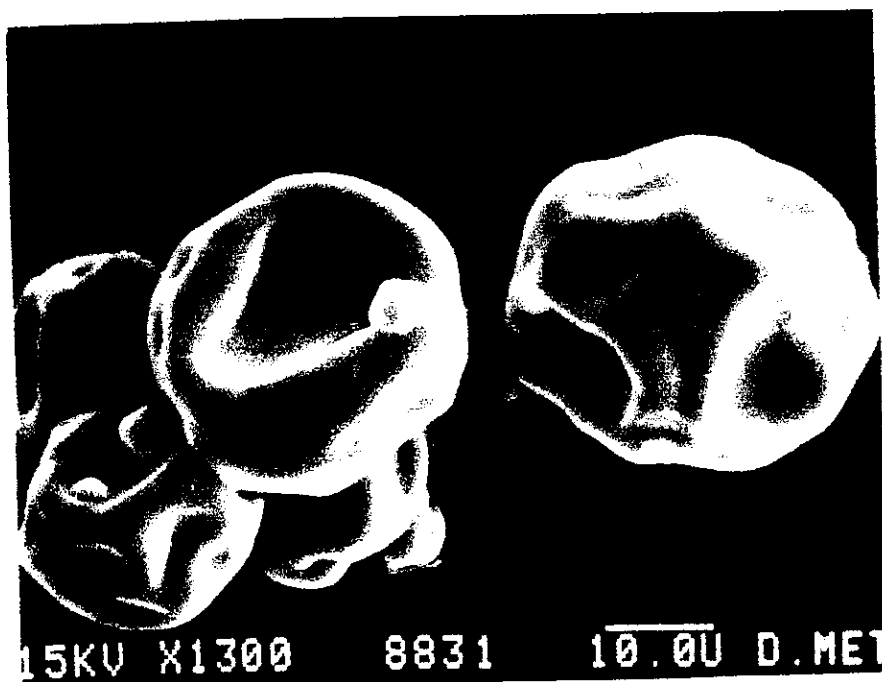
GA66-GM17-MD17 pH 4, rel 2:1  
74% humedad relativa



GA66.GM17-MD17 pH 4, rel 3:1  
74% humedad relativa



GA66-GM17-MD17 pH 8, rel 2:1  
74% humedad relativa



GA66-GM17-MD17 pH 8, rel 3:1  
74% humedad relativa



GA17-GM66-MD17 pH 4, rel 2:1  
74% humedad relativa



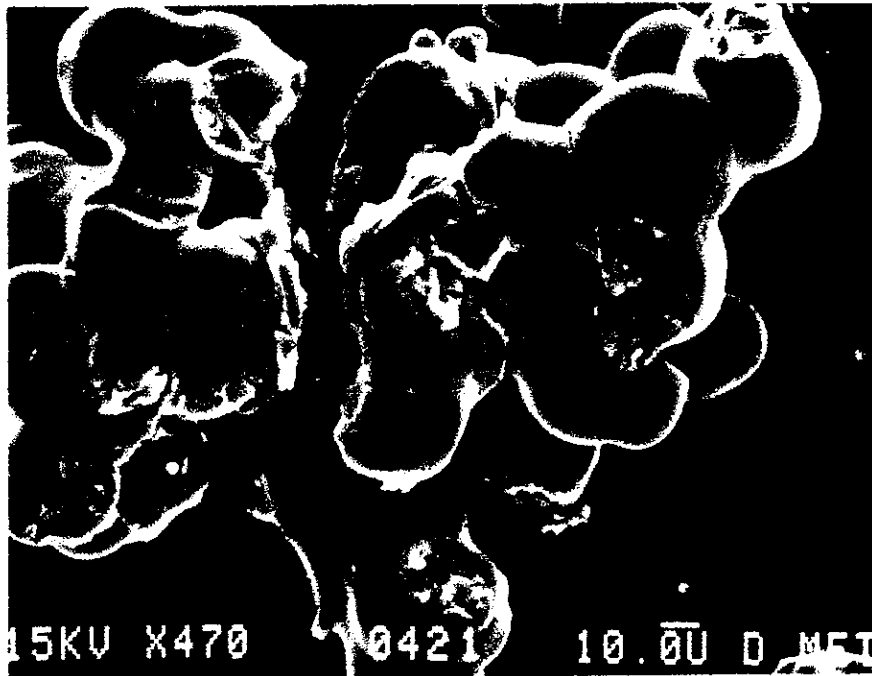
GA17-GM66-MD17 pH 4, rel 3:1  
74% humedad relativa



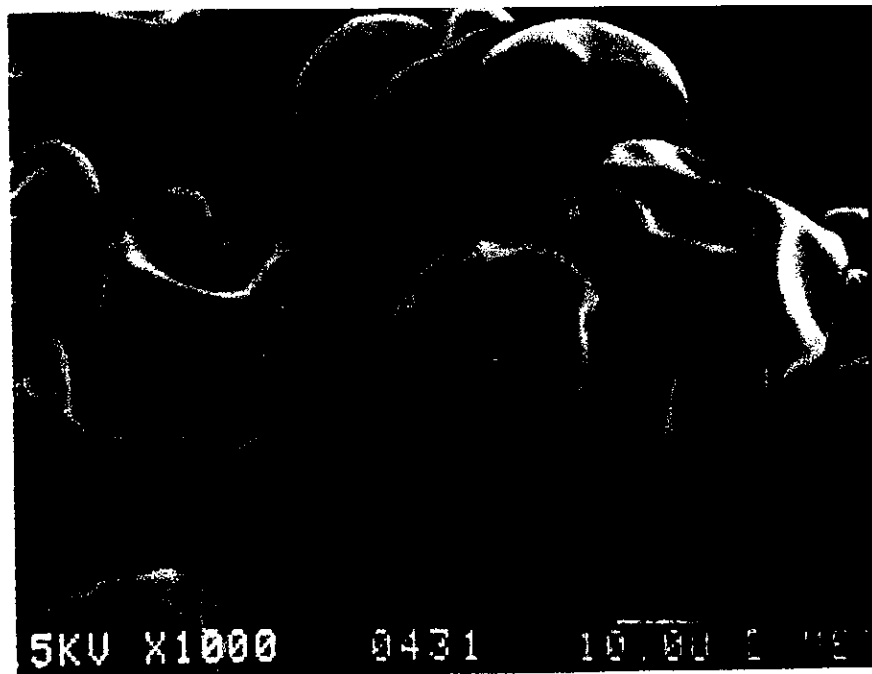
GA17-GM66-MD17 pH 8, rel 2:1  
74% humedad relativa



GA17-GM66-MD17 pH 8, rel 3:1  
74% humedad relativa



GA17-GM17-MD66 pH 4, rel 2:1  
74% humedad relativa



GA17-GM17-MD66 pH 4, rel 3:1  
74% humedad relativa



GA17-GM17-MD66 pH 8, rel 2:1  
74% humedad relativa



GA17-GM17-MD66 pH 8, rel 3:1  
74% humedad relativa