THE REFINING OF LEAD BULLION BY VACUUM DISTILLATION: A LITERATURE SURVEY

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Introduction

- Vacuum metallurgy is an important process in metallurgical processing [1]. It is less pollutant, and the operation conditions are good.
- Traditional methods of refining [2]:
  - Softening
  - Harris
  - Electrolysis
- Impurities to remove: Cu, Ag, As, Sb, Sn, Bi, Zn

Aim

- Investigation of vacuum distillation as an alternative process to refine crude lead.

T-x-y, P-x-y Diagrams

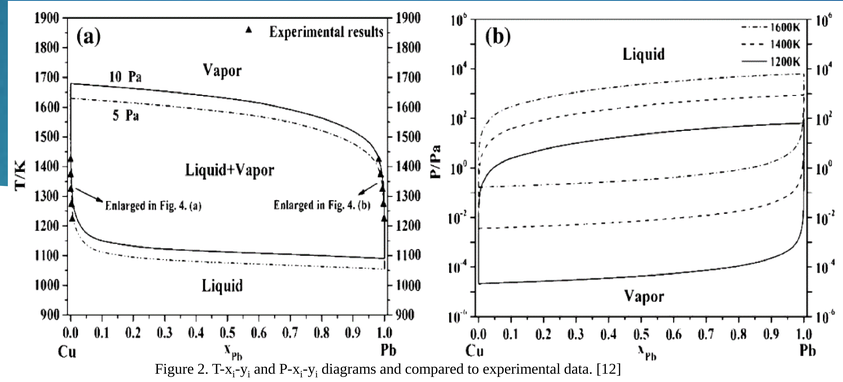

Figure 2. T-x_i-y_i and P-x_i-y_i diagrams and compared to experimental data. [12]

Discussion

- Removal of As, Sb, Zn from Pb
- Removal of Pb from Cu, Ag, and Sn
- Slight Removal of Bi from Lead

Conclusion

- Vacuum distillation is clean, pollutes less
- Vacuum distillation can be applied to refining of lead.

Thermodynamics of Vacuum Distillation

- Separation based on volatility of constituents (vapor pressure)
- Vapor pressure by the Clausius-Clapeyron equation: P in atm and T in K
- When present in an alloy, the partial pressure is $P_i = x_i \gamma_i P_i^*$
- Separation coefficient $\beta = \frac{\gamma_i P_i^*}{\gamma_{Pb} P_{Pb}^*}$

$$\boldsymbol{log\ P^* = A * T^{-1} + B * Log(T) + C * T + D}$$

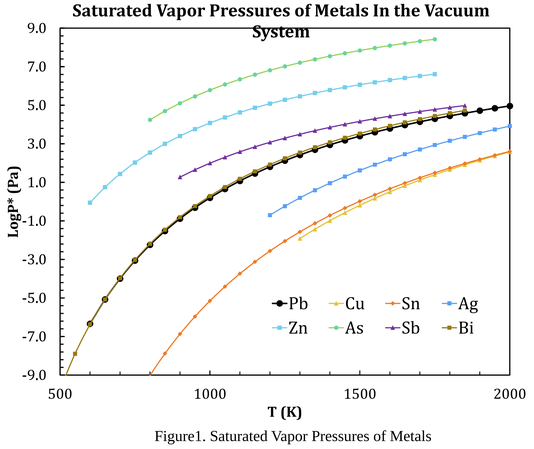

Figure1. Saturated Vapor Pressures of Metals

Activity Coefficient (γ_i) Models

- Molecular interaction volume model (MIVM) [2-7]
- Non-random two liquid (NRTL) [8],
- Wilson equation [9-11]

MIVM

$$\ln\gamma_i = \ln\left(\frac{V_{mi}}{x_i V_{mi} + x_j V_{mj} B_{ji}}\right) + x_j\left(\frac{V_{mj}B_{ji}}{x_i V_{mi} + x_j V_{mj} B_{ji}} - \frac{V_{mi}B_{ij}}{x_j V_{mj} + x_i V_{mi} B_{ij}}\right) - \frac{x_j^2}{2}\left(\frac{Z_i B_{ji}^2 \ln B_{ji}}{(x_i + x_j B_{ji})^2} + \frac{Z_j B_{ij} \ln B_{ij}}{(x_j + x_i B_{ij})^2}\right)$$

$$\ln\gamma_j = \ln\left(\frac{V_{mj}}{x_j V_{mj} + x_i V_{mi} B_{ij}}\right) - x_i\left(\frac{V_{mj}B_{ji}}{x_i V_{mi} + x_j V_{mj} B_{ji}} - \frac{V_{mi}B_{ij}}{x_j V_{mj} + x_i V_{mi} B_{ij}}\right) - \frac{x_i^2}{2}\left(\frac{Z_j B_{ij}^2 \ln B_{ij}}{(x_j + x_i B_{ij})^2} + \frac{Z_i B_{ji} \ln B_{ji}}{(x_i + x_j B_{ji})^2}\right)$$

$V_{m,i} V_m j$: *Molar volumes of components i and j*
B_{ij}, B_{ji}: *Pair − potential energy interaction paremeters* $(B_{ij} \neq B_{ji})$
Z_i, Z_j: *coordination number of i and j*

NRTL Model

$$\ln\gamma_i = x_j^2\left[\frac{\tau_{ji}G_{ji}^2}{(x_i + x_j G_{ji})^2} + \frac{\tau_{ij}G_{ij}}{(x_j + x_i G_{ij})^2}\right] \qquad \ln\gamma_i^\infty = \tau_{ji} + \tau_{ij}\exp(-\alpha_{ij}\tau_{ij})$$

$$\ln\gamma_j = x_i^2\left[\frac{\tau_{ij}G_{ij}^2}{(x_j + x_i G_{ij})^2} + \frac{\tau_{ji}G_{ji}}{(x_i + x_j G_{ji})^2}\right] \qquad \ln\gamma_j^\infty = \tau_{ij} + \tau_{ji}\exp(-\alpha_{ji}\tau_{ji})$$

$$\tau_{ji} = \frac{g_{ji} - g_{ii}}{RT} \qquad G_{ji} = \exp(-\alpha_{ji}\tau_{ji})$$

$\tau_{ij}\tau_{ji}$: *Energy parameters,* $(\tau_{ij} \neq \tau_{ji})$; g_{ij}, g_{ji}: *energy interaction of* $i-j$ *pair*
α_{ij}, α_{ji}: *Energy parameter* $(\alpha_{ij} = \alpha_{ji})$

Wilson Equation

$$\ln\gamma_i = -\ln(x_i + x_j A_{ij}) + x_j\left(\frac{A_{ij}}{x_i + x_j A_{ij}} - \frac{A_{ji}}{x_j + x_i A_{ji}}\right)$$

$$\ln\gamma_j = -\ln(x_j + x_i A_{ji}) - x_i\left(\frac{A_{ij}}{x_i + x_j A_{ij}} - \frac{A_{ji}}{x_j + x_i A_{ji}}\right)$$

A_{ij}, A_{ji}: *Wilson Parameters* $(A_{ij} \neq A_{ji})$

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Acknowledgments

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