Modelling of the Vanadium-Production from petroleum residues with Fact Sage

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Abstract

In petrochemical refining vanadium and nickel are retained in boiler residues and fly ashes from incineration or gasification. Vanadium and nickel are valuable metals that are wanted to be recovered. Soda ash (Na_2CO_3) is added to the petroleum residues (below referred to as vanadium concentrates) and the material is roasted at about 900 °C in a gas fired rotary kiln to form sodium vanadate and a nickel-iron-sufide matte (mixed liquid phase of FeS and Ni_3S_2). When tapping the molten sodium vanadate and the matte can easily be separated by density. The addition of soda ash causes two important reactions:

1. Formation of sodium vanadate

   Three compounds with different sodium content can form:
   - Sodium meta-vanadate: $(Na_2O)(V_2O_5) = Na_2V_2O_6 = 2\ NaVO_3$
   - Sodium pyro-vanadate: $(Na_2O)_2(V_2O_5) = Na_4V_2O_7$
   - Sodium ortho-vanadate: $(Na_2O)_3(V_2O_5) = Na_6V_2O_8 = 2\ Na_3VO_4$

   The predominant product of the introduced process the sodium pyro-vanadate.

2. Prevention of SO_X by forming sodium sulphate Na_2SO_4

   The metals (V, Ni and Fe) are retained in the vanadium concentrates as sulphates ($VOSO_4$, $NiSO_4$ and $Fe_2(SO_4)_3$). Thus, when forming sodium vanadate and matte, SO_2 is released according to the following equations:

   $4\ VOSO_4 + 4\ Na_2CO_3 \rightarrow 2\ Na_4V_2O_7 + 4\ SO_2 + 4\ CO_2 + O_2$

   $3\ NiSO_4 + Fe_2(SO_4)_3 + 10\ C \rightarrow Ni_3S_2 + 2\ FeS + 2\ SO_2 + 10\ CO_2$

   By adding additional soda ash the formation of SO_2 can be avoided. The above equations change into:

   $4\ VOSO_4 + 8\ Na_2CO_3 + O_2 \rightarrow 2\ Na_4V_2O_7 + 4\ Na_2SO_4 + 8\ CO_2$

   $3\ NiSO_4 + Fe_2(SO_4)_3 + 2\ Na_2CO_3 + 9\ C \rightarrow Ni_3S_2 + 2\ FeS + 2\ Na_2SO_4 + 10\ CO_2$

Two important questions can be answered by performing FactSage calculations:

1. How much soda ash is required to form sodium vanadate and to avoid the formation of SO_X in the flue gas?

   Answer: Using the Equilib module different amounts of soda ash can be added to the vanadium concentrates. With a plot of the results one can read off the optimum amount of soda ash.

2. Under which conditions do the sodium vanadate and the matte form simultaneously?

   Answer: Using the Phase Diagram module a predominance area of the sodium pyro-vanadate and the matte can be calculated. As x-axes temperature and as y-axes the oxygen partial pressure were chosen.