Exercise 1.10. Absorption of competitive species: SO_2 vs. CO_2

A flue gas contains 44,000 ppm of CO_2 and 300 ppm of SO_2; the scrubbing liquor pH is 7. Flue gas stream: 42,500 m^3/h *(= 11.8 m^3/s),* at 66 ºC. Blow-down: 1.0 m^3/h (liquor discharged).
At pH 7: $K_{H(CO2)}$ = 0.2 M/atm; $K_{H(SO2)}$ = 3 x 10^5 M/atm. (Both: H_{eff} !)

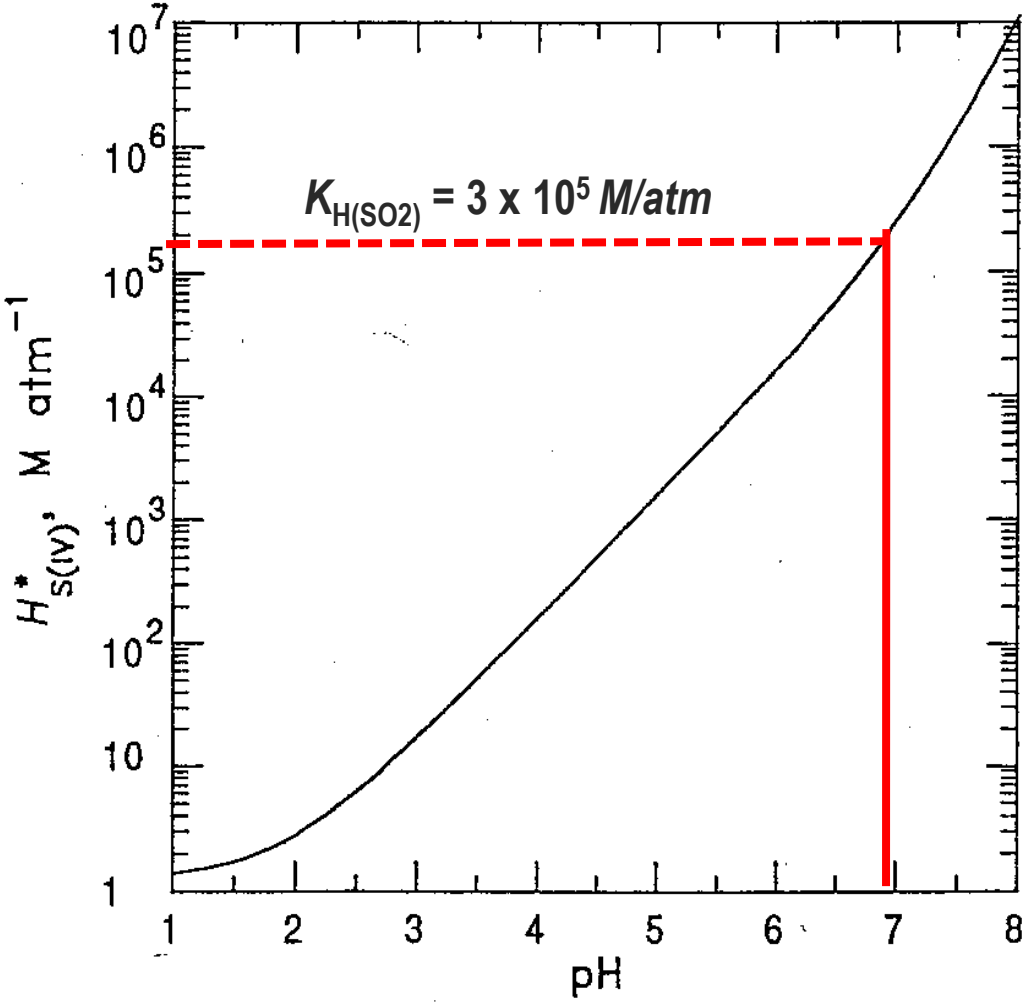
A) Calculate $[CO_2]aq.$;

B) To keep $(SO_2)_g$ < 5 ppm in the cleaned gas, what can be the max SO_2 concentration in the scrubbing liquor?

C) the amount of SO_2 to be removed in mol/h, and kg/h;

D) $[SO_2]aq$ in the scrubbing liquor (= blow-down conc.!).

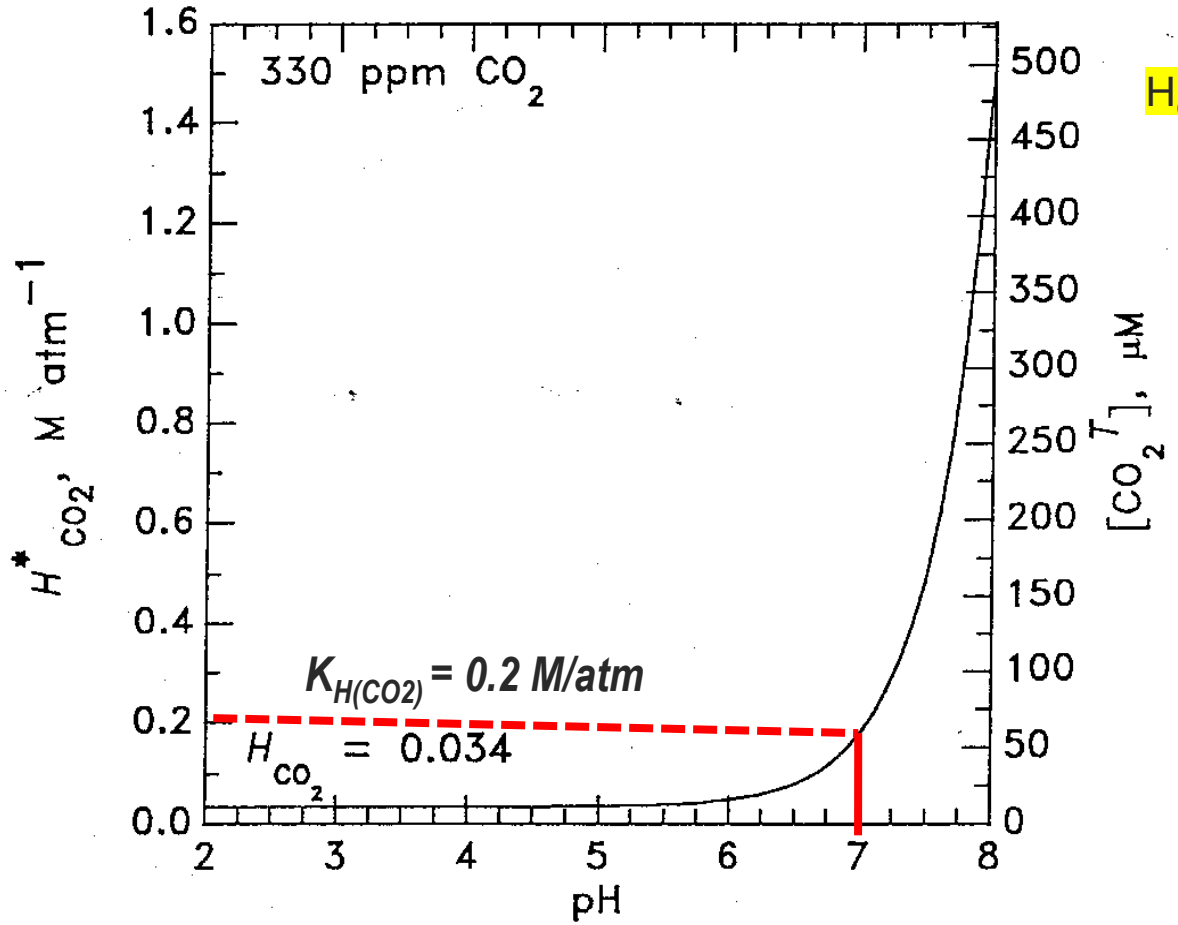
Effective Henry's Law Constant of SO_2 as a Function of pH



H_{eff} increases with ph

FIGURE 6.6 Effective Henry's law constant for SO_2 as a function of solution pH at 298 K.

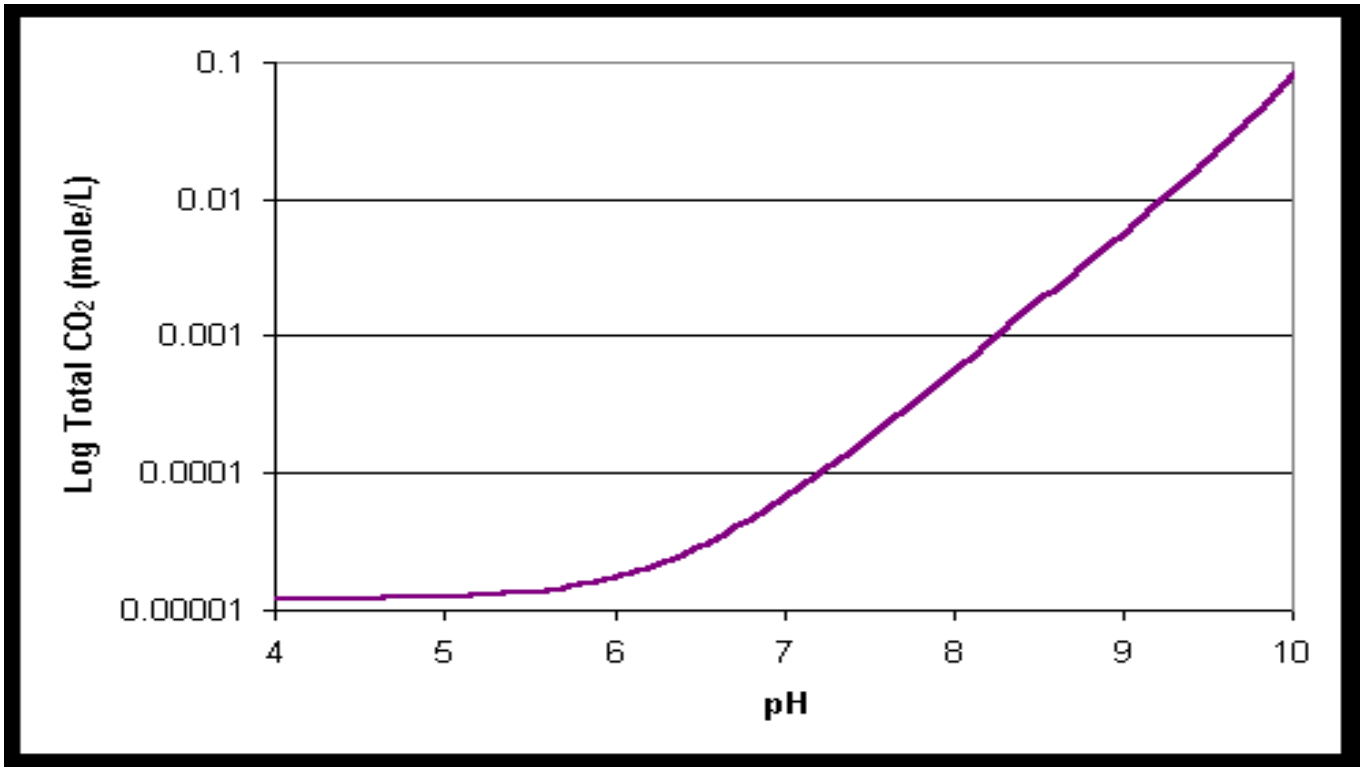
Effective Henry's Law Constant of CO_2 as a Function of pH



H_{eff} increases with ph

FIGURE 6.4 Effective Henry's law constant for CO_2 as a function of the solution pH. Also shown is the corresponding equilibrium total dissolved CO_2 concentration $[CO_2^T]$ for a CO_2 mixing ratio of 330 ppm.

Effective Henry's Law Constant of CO_2 as a Function of pH



Exercise 1.10. Absorption of competitive species: SO_2 vs. CO_2 - solution

A) *$CO_{2(g)}$=44,000 ppm = 4.4% v/v; $P_{CO2}=x_{CO2}\,P$ =0.044 x 1 = 0.044 atm*

$[CO_2]_{aq} = K_H\,P_{CO2}$

$[CO_2]_{aq}$ = 0.2 x p_{CO2} = 0.2 x 0,044 = ***8.8 mM*** *(=0.4 g/L; CO_2 absorbed ≈ 1%)*

B) *$SO_{2(g)}$ = 5 ppm;* ***$P_{SO2} = x_{SO2} \cdot P = 5 \cdot 10^{-6} \cdot 1 = 5.0 \cdot 10^{-6}$ atm***

$[SO_2]_{aq}$ in eq. with SO_2 gas 5 ppm = $K_H\,P_{SO2}$

$[SO_2]_{aq} = 3 \cdot 10^5$ M/atm x $5 \cdot 10^{-6}$ atm = ***1.5 M*** *(max. conc. in solution in eq. with 5 ppm SO_2 in the gas phase)*

C) $SO_{2(g)}$ to be removed: *(300-5) ppm x 42,500 m^3/h = 12.5 m^3/h*

The flue gas is at 66°C and 1 atm (actual condition). In order to convert to reference conditions (t=0°C; p=1 atm) you can apply the following expression previously introduced:

$$Q_a = Q_n \frac{P_n \cdot T_a}{P_a \cdot T_n}$$

Therefore,

$SO_{2(g)}$ to be removed: = 12.5 m^3/h = 10.1 Nm^3/h

According to Avogadro's rule at T=0°C (273 K) and P=1 atm ,1 mole of any ideal gas has a volume of 22,4 l.

$SO_{2(g)}$ to be removed: = 10.1 / 22.4= 0.45 kmol/h

The MW of SO_2 is 64, then:

*$SO_{2(g)}$ to be removed: = 0.45 *64 =28.8 kg SO_2/h*

Exercise 1.10. Absorption of competitive species: SO_2 vs. CO_2 - solution

D) Concentration of "SO_2" in the liquor:

$[SO_2]_{aq}$ blowdown = *Nr moles /Volume = 0.45 kmol/h / 1.0 m^3/h = 0.45 mol/L =* ***0.45 M***

Note 1. **The system can really work!** In fact, the concentration of SO_2 in the blow-down liquor is **<** than the maximum conc. permitted by Henry law, that is 1.5 M. **If SO_2 conc. in the blow-down is > than 1.5 M, you cannot reduce the SO_2 conc. down to 5 ppm in the cleaned gas ! The higher the blow-down, the lower the pollutants concentrations in the cleaned gas!**)

Note 2. At pH 7 there is no SO_2 in the aq. phase, but only HSO_3^- (≈70%) and SO_3^{2-} (≈30%) (see Figure in the next slides)

Conclusion: At pH = 7, flue gases can be efficiently desulfurated ,whilst keeping CO_2 absorption at low levels! What about pH 8? What about pH 6?