OTHER PHYSICAL SOLVENTS

Woertz (6.13) has investigated a number of physical solvents for possible use in natural gas sweetening. The solvents investigated included methyl cyanoacetate (MCA), glutaronitrile, ethylene cyanohydrin and methyl acetoacetate, among others. Table 6.16 summarizes the physical properties of a number of these solvents and compares them with others in commerical use including propylene carbonate, N-methyl pyrrolidone, the dimethyl ether of diethylene glycol and sulfolane. Table 6.17 summarizes the solubilities of CO_2, H_2S and propane in these solvents and compares them.

Table 6.16 Properties of Various Solvents

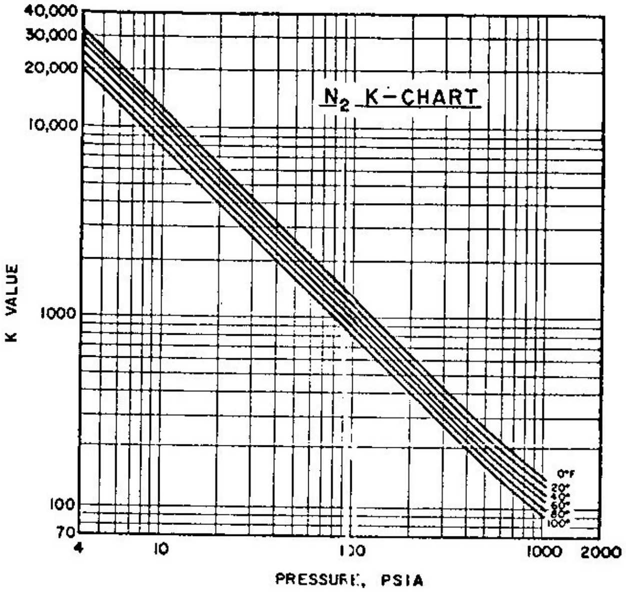
SOLVENT	ATM, B.P., °F.	FREEZING POINT, °F.	VISCOSITY CS at 100°F.	MOL. WT.	DENSITY GM/ML, 60°F.	WATER MISCIBILITY
METHYL CYANOACETATE	395	-9	1.83	99.09	1.1329	NO
GLUTARONITRILE	549	-20	4.53	94.11	0.9939	NO
PROPYLENE CARBONATE	467	-56	1.65	102.09	1.2101	NO
TRIMETHYLENE CYANOHYDRIN	464?	LOW		85.11	1.1036	YES
N-METHYL PYRROLIDONE	396	-12	1.65CP (77°F.)	99.13	1.027	YES
DIMETHYL FORMAMIDE	307	-78	0.802CP (77°F.)	73.09	0.9467	YES
DEG DIMETHYL ETHER	324	-83	2.0 CP (68°F.)	134.17	0.945	YES
SULFOLANE	546	77	10.34CP (86°F.)	120.17	1.261	YES

Table 6.17 Solubility of Gases in Selective Solvents at 80°F and Atmospheric Pressure

SOLVENT	SOLUBILITY Vol/Vol/ATM CO_2	Propane	H_2S	CO_2/Propane Ratio
Methylcyanoacetate	3.22	1.34	10.7	2.40
Glutaronitrile	2.65	1.156	11.5	2.29
Propylene Carbonate	3.20	1.84	11.6	1.74
Trimethylene Cyanohydrin	3.30	1.98	15.4	1.67
N-Methyl Pyrrolidone	4.56	3.78		1.28
Dimethyl Formamide	4.86	3.89	38.1	1.25
Diethylene Glycol Dimethyl Ether	4.63	4.68		0.989
Sulfolane	0.839	1.17		0.717

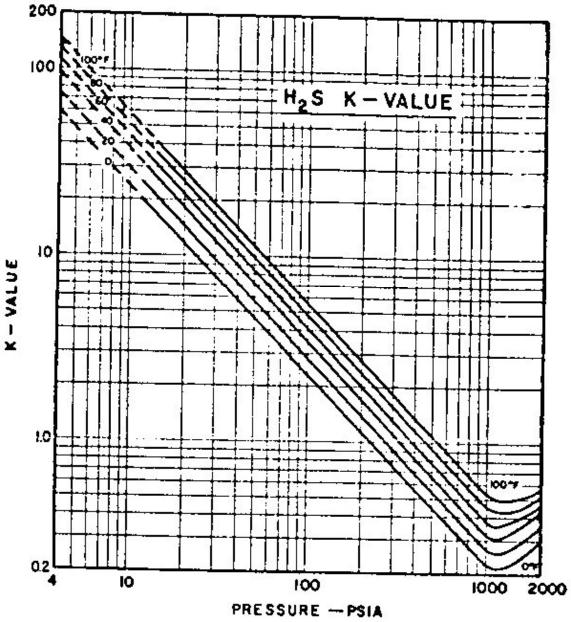
Equilibrium Constants for MCA

Based on these data as well as pilot plant operations (6.14, 6.15), Woertz has derived equilibrium constants for the acid gases and paraffin hydrocarbons in MCA. These equilibrium constants are shown in Fig. 6.29 to 6.41. They represent probably the most complete set of equilibrium constant information available on any of the physical solvents used in proprietary processes.



K-CHART FOR NITROGEN IN METHYL CYANOACETATE.

Figure 6.29



K-VALUE OF H_2S IN METHYL CYANOACETATE.

Figure 6.30

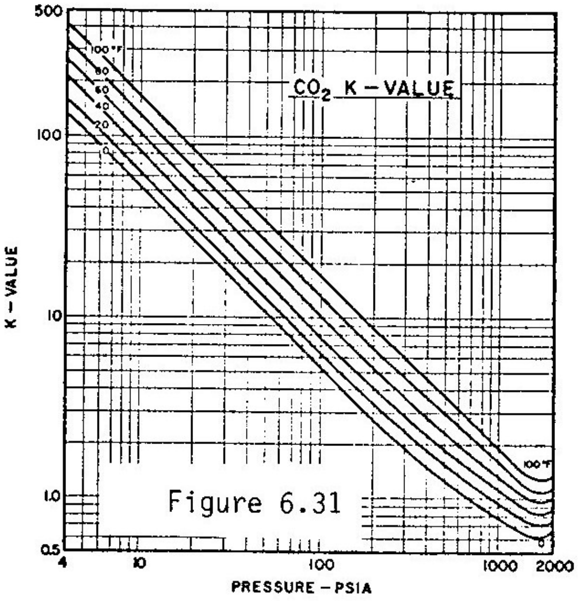


Figure 6.31

K-VALUE OF CO_2 IN METHYL CYANOACETATE.

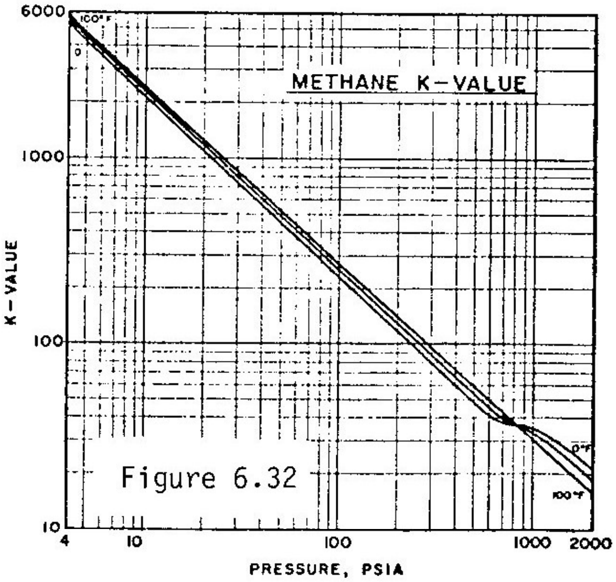
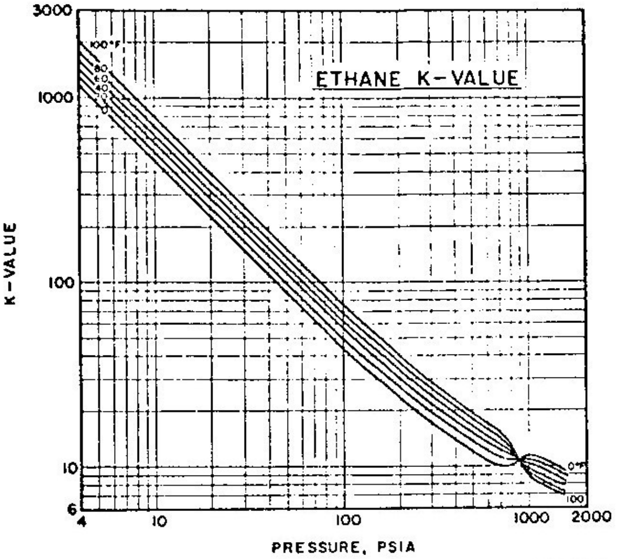


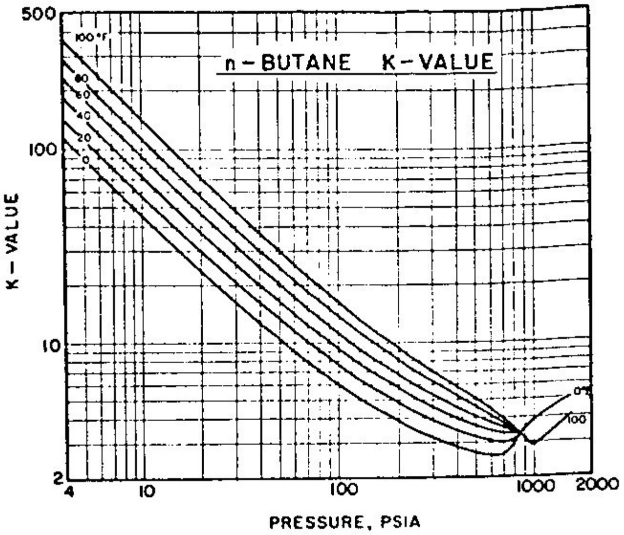
Figure 6.32

K-VALUE OF METHANE IN METHYL CYANOACETATE.

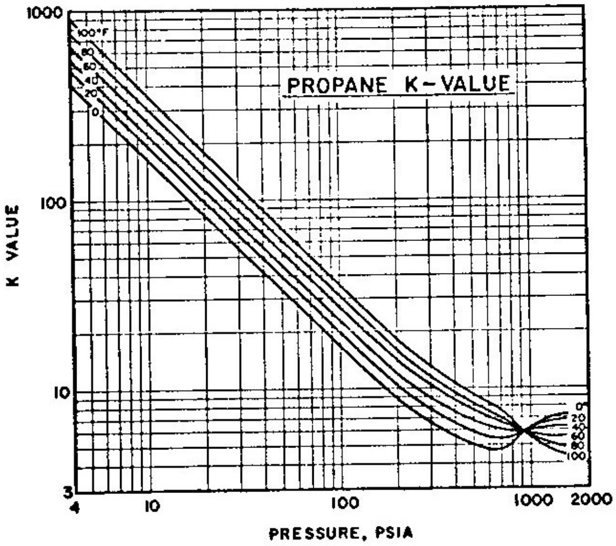
Figures 6.29-6.32 Equilibrium charts for natural gas components in MCA. (Ref. 6.14 Courtesy SPE)



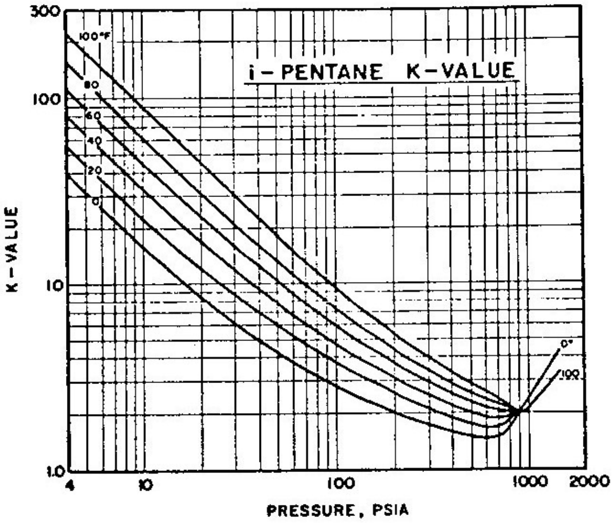
K-VALUE OF ETHANE IN METHYL CYANOACETATE.



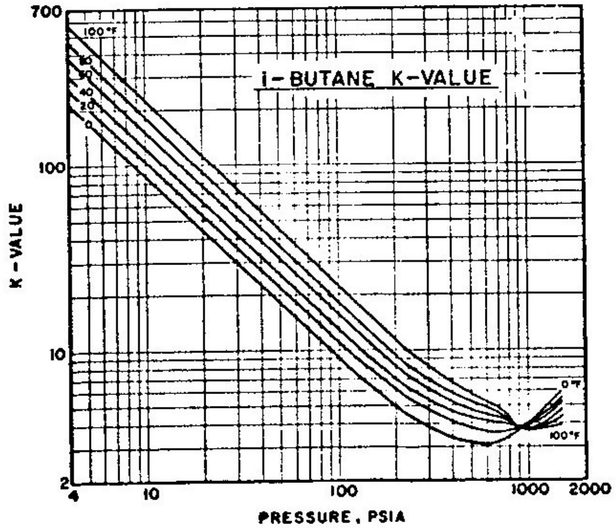
K-VALUE OF *n*-BUTANE IN METHYL CYANOACETATE.



K-VALUE OF PROPANE IN METHYL CYANOACETATE.



K-VALUE OF *i*-PENTANE IN METHYL CYANOACETATE.

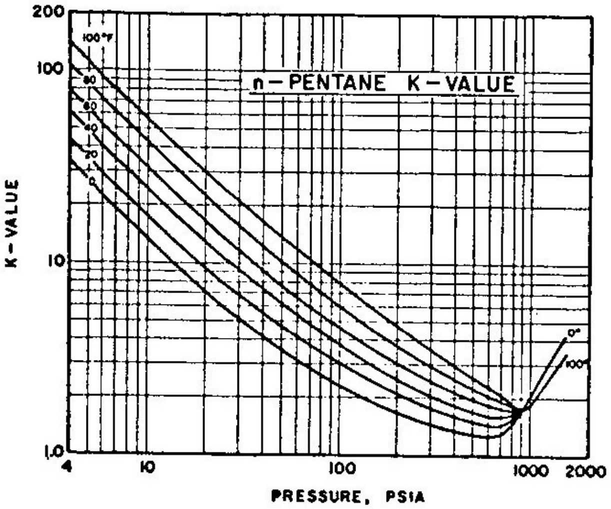


K-VALUE OF *i*-BUTANE IN METHYL CYANOACETATE.

Figures 6.33-6.37

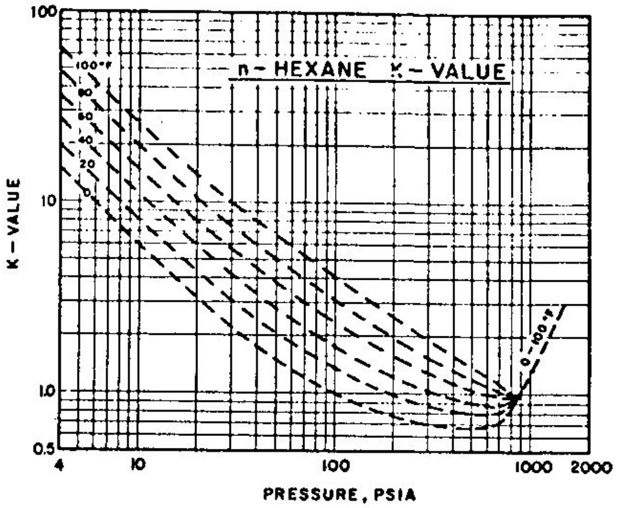
Equilibrium charts for natural gas components in MCA

(Ref. 6.14 Courtesy SPE)



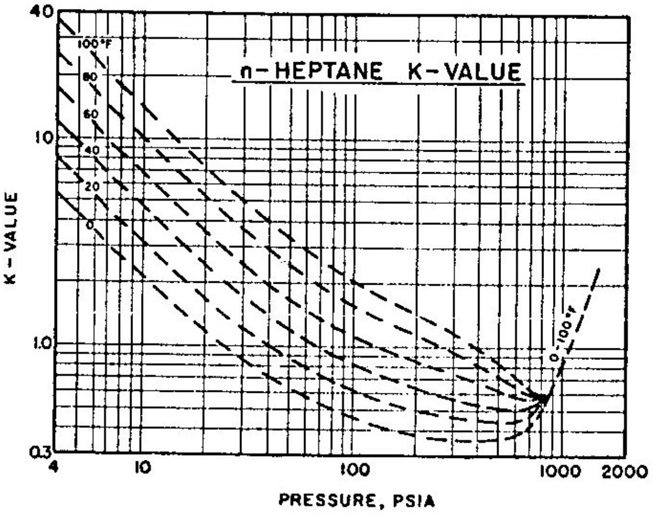
K-VALUE OF *n*-PENTANE IN METHYL CYANOACETATE.

Figure 6.38



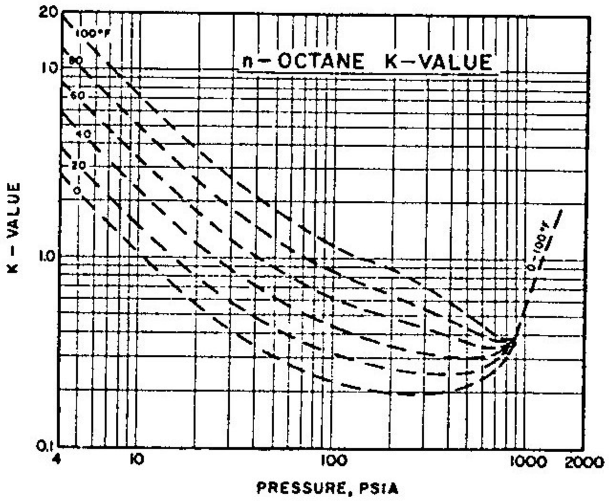
K-VALUE OF *n*-HEXANE IN METHYL CYANOACETATE.

Figure 6.39



K-VALUE OF *n*-HEPTANE IN METHYL CYANOACETATE.

Figure 6.40



K-VALUE OF *n*-OCTANE IN METHYL CYANOACETATE.

Figure 6.41

Figures 6.38-6.41 Equilibrium charts for natural gas components in MCA. (Ref. 6.14 Courtesy SPE)

Example Problem

Gas of the composition shown below is available at 100°F. and 800 psia. What circulation rate of methylcyanoacetate will be required to absorb 90% of the hydrogen sulfide in the gas stream?

Solution

From Fig. 2.12 (absorption factor chart) the absorption factor for hydrogen sulfide is determined to be 0.98. The equilibrium constant for each component is read from the appropriate chart in Fig. 6.29 to 6.41. Using the absorption factor for hydrogen sulfide we can determine the circulation rate to be:

$$A = 0.98 = \frac{L_o}{0.66V_{N+1}} ; \frac{L_o}{V_{N+1}} = 0.647$$

With the value for circulation fixed the absorption factor can be calculated for each component, and Fig. 2.12 used to determine the fractional absorption as shown in the table below.

Comp	Mol %	K	A	a	Mols Abs'd	Mol %
CO_2	10.0	2.4	0.27	0.27	2.7	3.54
H_2S	5.0	0.66	0.98	0.9	4.5	5.89
C_1	75.0	39.	0.017	0.017	1.28	1.68
N_2	5.0	1.0	0.0038	0.0038	0.02	0.03
C_2	3.0	1.4	0.462	0.462	1.39	1.82
C_3	2.0	0.68	0.951	0.885	1.77	2.32
MCA					64.70	84.72
					76.36	100.00

The circulation rate for 1 MMSCFD of gas flow would be:

$$\frac{2636 \times 0.647 \times 99.09}{1440 \times 1.132 \times 8.33} = 12.4 \text{ gal/mm}$$

In cases where physical solvents are used to remove extremely large precentages of the acid gases the conventional plot of the absorption factor equation shown in Fig. 2.12 is not sufficient. Valentine (6.21) showed another graphical solution for the absorption factor equation that yields itself to those solutions. It is shown in Fig. 6.42.

Example Problem

We desire to recover 65% of a component from a gas stream. With the solvent used and at the temperature and pressure of the absorber the equilibrium constant (K) for the component is 1.2. How much solvent must be circulated over the absorber?

Solution

We will use Equ. 2.24. If we assume that the solvent is completely free of the component to be absorbed, Y_o will be zero and

$$\frac{Y_{n+1} - Y_1}{Y_{n+1}} = \frac{A^{n+1} - A}{A^{n+1} - 1}$$

In this form the left hand side of the equation represents the fraction of the component absorbed or, in our case, 0.65. If the absorber contains the equivalent of four theoretical trays we determine from Fig. 2.12 that the absorption factor A must be equal to 0.715.

$$A = \frac{L_o}{KV_{n+1}} \qquad 0.715 = \frac{L_o}{1.2V_{n+1}}$$

$$\frac{L_o}{V_{n+1}} = 0.858 \text{ mols solvent/mol gas}$$