PHYSICAL PROPERTIES RELEVANT TO ACID GAS INJECTION

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Acid gas injection has become established as an environmentally friendly way to dispose of unwanted hydrogen sulfide and carbon dioxide, the so-called acid gases. In Western Canada there are approximately 25 injection projects currently in operation.

The design of an acid gas injection scheme requires a significant amount of information regarding physical properties. These include: (1) enthalpy, entropy, and heat capacity for compressor design; (2) enthalpy for coolers; (3) density and viscosity for pipelines and injection wells In addition, the thermal conductivity is required for heat transfer calculations throughout. As has been previously demonstrated, the density is the key parameter in establishing the required injection pressure (Carroll and Lui, 1997).

The purpose of this paper is to review the literature for the available experimental data and survey methods for calculating of the various properties of acid gases. This study will be limited to the following components: hydrogen sulfide, carbon dioxide, and methane. Water will only be considered inasmuch as it is a relatively minor component in the acid gas mixture. Only gaseous and liquefied acid gas phases will be considered, not the aqueous phase. Methods will include equations of state, corresponding states, kinetic-theory-based models, and empirical models.

INTRODUCTION

Hydrogen sulfide and carbon dioxide are common contaminants of natural gas and are removed from the natural gas in order to produce a sales gas. Hydrogen sulfide and carbon dioxide are called "acid gases" because when dissolved in water they form weak acids.

Hydrogen sulfide must be removed from natural gas because of its high toxicity and strong, offensive odor. Carbon dioxide is removed because it has no heating value. Another reason why these gases must be removed is because they are corrosive. Typically sales gas must contain less than 16 ppm hydrogen sulfide and less than 2% carbon dioxide, however different jurisdictions have different standards.

Once removed from the raw gas, the question arises as to what should be done with the acid gas? If there is a large amount of acid gas it may be economical to build a Claus-type sulfur plant to convert the hydrogen sulfide into the more benign elemental sulfur. For small acid gas streams sulfur plants are not feasible. In the past it was permissible to flare small amounts of acid gas. However, with growing environmental concerns, such practices are being legislated out of existence.

In addition, the disposal of carbon dioxide to the atmosphere is becoming an undesirable practice. Whether or not one believes that CO_2 is harmful to the environment has almost become a mute point. It is clear that legislators around the world believe it is a problem and are prepared to take action. In some countries a carbon tax applied to such disposal. Engineers will increasingly be faced with the problem of disposing of CO_2.

Acid gas injection, compression of the acid gas for injection into a deep formation, has quickly become the method of choice for the disposal of such gases.

The foundation of a good process design is accurate physical property calculations. This is no less true for acid gas injection than for any design. The design of an acid gas injection scheme requires knowledge of the density, enthalpy, entropy, viscosity, thermal conductivity, and other properties of the acid gas mixtures.

In this paper, techniques are presented for estimating the physical properties of fluids along with some recommended values for hydrogen sulfide, carbon dioxide, methane, and water – the last

two being the major impurities in acid gas. However, we will concentrate on the physical properties of hydrogen sulfide and carbon dioxide and mixtures of these two components.

This discussion is not meant to be a thorough review of the science of physical property estimation. For a thorough review the reader is referred to the book by Reid et al. (1987) and earlier editions of their text.

To begin, several properties for the four components mentioned above are summarized in Table 1. These values come from various sources and are used throughout this text in the example problems.

PROPERTIES OF CARBON DIOXIDE

There is significantly more data available for carbon dioxide than for hydrogen sulfide, particularly for transport properties. One reason for this is that carbon dioxide is significantly easier to deal with than hydrogen sulfide. In addition, carbon dioxide has a much lower critical point placing this interesting region in a range more accessible to experimenters. The vicinity near the critical point is attractive to researchers because of the nature of the physical properties in that region – the properties change dramatically with small changes in either the temperature or the pressure.

Thermodynamic properties were reviewed by Angus et al. (1976) and tables of thermodynamic properties were constructed. Vukalovich and Altunin (1968) reviewed both the thermodynamic and transport properties. These are similar to the *Steam Tables* (Haar et al., 1984), which should be familiar to most engineers.

The physical properties of saturated liquid carbon dioxide are listed in Table 2 and those for the saturated vapor are in Table 3. The properties are compiled from several sources including Vukalovich and Altunin (1968), Golubev (1970), and Angus et al. (1976). The values in these tables represent a compromise between the various sets of data.

Here are a few comments on the values in the tables. First, the density of liquid carbon dioxide is only slightly less than water. At the temperatures listed in the table, carbon dioxide is fairly compressible since it is near its critical temperature. Under pressure, carbon dioxide becomes more dense than water.

The infinite heat capacity at the critical point looks unusual, but this is true of all pure substances. This has been observed experimentally and can be demonstrated using the principles of classical thermodynamics. However, even though the heat capacity is infinite, the enthalpy at the critical point is finite.

PROPERTIES OF HYDROGEN SULFIDE

As was mentioned earlier, there is significantly less data available for hydrogen sulfide than for carbon dioxide, particularly for the transport properties. This is partially because of the high toxicity of H_2S, which makes it difficult to study in the laboratory. To get around this issue the data for carbon dioxide, combined with the principle of corresponding states, will be used to approximate the transport properties of H_2S.

Goodwin (1983) reviewed the thermodynamic properties of hydrogen sulfide. Using an advanced equation of state a table of properties was constructed over a wide range of pressures and temperatures.

Experimental measurements of the transport properties of hydrogen sulfide are quite rare. A corresponding states approach was used to estimate the transport properties of H_2S.

The physical properties of saturated liquid hydrogen sulfide are listed in Table 4 and those for the saturated vapor are in Table 5. The vapor pressure, densities, and heat capacities are taken from Goodwin (1983). Transport properties were estimated using techniques given by Neuberg et al. (1977) and from a corresponding states interpretation of the CO_2 values. The transport properties given in these tables should be considered as preliminary and subject to change.

ESTIMATION TECHNIQUES FOR PHYSICAL PROPERTIES

There are many methods for estimating the physical properties of fluids. In this section we will discuss those which are appropriate for acid gases. However, these methods tend to be more general in nature.

In this discussion, the thermodynamic properties (P-v-T [density], enthalpy, entropy, and heat capacity) and transport properties (viscosity and thermal conductivity) will be treated separately.

Thermodynamic Properties

Ideal Gas

At low pressure, less than about 300 kPa, it is safe to assume that the acid gas mixture behaves as an ideal gas. The first consequence of assuming ideal gas behavior is that the density can be easily calculated from the ideal gas law:

$$\rho = \frac{MP}{RT} \tag{1}$$

where: ρ – density, kg/m³

M – molar mass, kg/kmol

P – pressure, kPa

R – universal gas constant, 8 314 m³•Pa/kmol•K

T – absolute temperature, K

The second consequence of the ideal gas assumption is that enthalpies are only a function of the temperature. The enthalpy change for an ideal gas can be readily calculated from:

$$h^* - h_{ref}^* = \int_{T_{ref}}^{T} C_P^* \, dT \tag{2}$$

where: h – molar enthalpy, J/mol

T – temperature, K

C_P – isobaric heat capacity, J/mol•K

The superscript * is used to indicate the ideal gas state and the subscript ref is a reference state, which is usually chosen for convenience. Ideal gas heat capacities are available for many components and are usually expressed in the form of a polynomial in temperature:

$$C_P^* = A + BT + CT^2 + DT^3 \tag{3}$$

Table 6 summarizes the ideal gas coefficients for the four components of interest here. When using these coefficients the temperature in Eqn (3) must be in Kelvin and the resulting heat capacity has units of J/mol•K. These values come from Reid et al. (1987).

Finally, the entropy change of an ideal gas can be calculated from the following expression:

$$s_2^* - s_1^* = \int_{T_1}^{T_2} \frac{C_P^*}{T} dT - R \, ln(P_2/P_1) \tag{4}$$

where: s – enthalpy, J/mol•K

The subscripts 1 and 2 represent arbitrary states. Note that the entropy change for an ideal gas is a function of both the temperature and the pressure. This is different from the enthalpy of an ideal gas, which is only a function of the temperature.

Real Gas

To calculate the density of a real gas the following equation is used:

$$\rho = \frac{MP}{zRT} \tag{5}$$

where: z – compressibility factor, unitless

The compressibility factor is usually calculated using either an equation of state or using the corresponding states principle. Both of these methods will be discussed later.

For the calculation of thermodynamic properties the cubic equations of state have become the workhorse of the process simulation business. In particular, the equations of state of Soave (1972) and of Peng and Robinson (1976) and modifications of these original forms are the most commonly used.

Although the equations of state have the form $P = f(T,v)$, in combination with the ideal gas heat capacities they can be used to calculate all of the thermodynamic properties, including phase equilibrium.

Figure 1 shows a comparison between the *IUPAC Tables* (Wagner et al., 1977) and the Peng-Robinson equation. The density of the saturated vapor is fairly accurately predicted by the equation of state, except for very close to the critical point. On the other hand, the predictions for the saturated liquid are not as good. At low temperatures the equation of state overestimates the density, whereas at high temperature it underestimates it. It is only in the region near the critical point that the errors become large. At –50°C the error in the predicted liquid density is about 3.5%, whereas at 20°C the error is about 7.5%. Such errors may be tolerable in some design calculation, but the design engineer should be aware of this potential problem.

Figure 2 is a similar plot to Fig. 1 except that this figure for hydrogen sulfide. The predictions from the Peng-Robinson equation are compared with the *NBS Tables* (Goodwin, 1983). Also note the similar behavior in the prediction of the densities.

Liquids

As with gases under pressure, the usual approach to calculate liquid densities is to use an equation of state. However, the commonly used equations of state are notoriously poor for estimating the densities of liquids. Eqn (5) can also be used for liquids, provided the appropriate compressibility factor is used. However, it is more common to use a correlation, such as COSTALD (Reid et al., 1987) for the liquid density.

Corresponding States

Essentially, the theorem states that if the properties are scaled properly then the scaled properties of all substances should be the same. Most applications of the theory begin with the critical point. Thus, we define the reduced temperature and reduced pressure as:

$$T_R = \frac{T}{T_C} \tag{6}$$

$$P_R = \frac{P}{P_C} \tag{7}$$

In its simplest form, the theory of corresponding states says that if two substances are at the same reduced temperature and reduced pressure, then the other "reduced" properties should be equal.

According to the principle, the properties of any fluid are dependent only on the reduced temperature and pressure. Therefore, the properties of a fluid depend only on its temperature and pressure relative to its critical point:

$$z = \frac{Pv}{RT} = g(T_R, P_R) \tag{8}$$

The z-factor thus obtained is used in Eqn. (5) in order to calculate the density of the gas.

The observation that the properties could be expressed in terms of the reduced quantities has many important ramifications. These including the possibility that if you plotted the reduced vapor pressure as a function of reduced temperature, all substances would fall onto a single curve. Furthermore, if you plotted the compressibility factor versus the reduced pressure with the reduced temperature as a parameter, all fluids would lie on the same plot, at least according to theory.

The two-parameter corresponding states principle is sufficiently accurate for approximations of the physical properties of simple fluids and its simplicity makes it attractive for such calculations. It can even provide reasonably accurate predictions for other fluids.

This simple method is still used in the hydrocarbon processing industries for rapid approximations of the density of natural gas.

Transport Properties

Low Pressure Gas

The kinetic theory of gases provides some basis for these correlations. Without going into the details, the kinetic theory predicts that for an ideal gas the viscosity and thermal conductivity are independent of the pressure and vary with the square root of the temperature. This can be used to

extrapolate data for gases over small ranges of pressure and temperature, even if the gas does not behave ideally.

At low pressure the viscosity and thermal conductivity are independent of the pressure. This is observed experimentally, in confirmation of the kinetic theory Therefore, these quantities can be expressed as a function of the temperature alone. Most of these correlations will also be based on the square root of the temperature, although the exact expressions tend to be more complicated.

Fig. 3 shows the low-pressure viscosity for the four gases of interest here.

Gases Under Pressure

Experience has shown that the viscosity of a gas under pressure is more highly correlated with the density than it is with either the temperature or the pressure or even a combination of both. This was clearly demonstrated by Herreman et al. (1970) for pure carbon dioxide.

The corresponding states method of Jossi et al. (Reid, et al., 1987) is used to correct for the high density:

$$[(\mu - \mu_o)\xi + 1]^{1/4} = 1.0230 + 0.23364\,\rho_R + 0.58533\,\rho_R^2 - 0.40758\,\rho_R^3 + 0.0923324\,\rho_R^4 \quad (9)$$

where: μ_o – low-pressure viscosity (from above)

ρ_R – reduced density ($\rho_R = \rho/\rho_C$)

The ξ in the above equation is calculated using the following:

$$\xi = \left[\frac{RT_C N_A^2}{M^3 P_C^4}\right]^{1/6} \quad (10)$$

where N_A – Avogadro's number, $6.022\text{x}10^{23}$ mol^{-1}

Note that this equation indicates that the high-pressure viscosity is a function of the density alone. All other parameters in this equation are either scaling factors or constants.

The correction is reported to be valid for the range $0.1 \leq \rho_R \leq 3$. In addition, this correlation was derived for non-polar gases, but it can be used for acid gas mixtures with the desired accuracy.

Liquids

Unfortunately, there is no good theory, equivalent to the kinetic theory that is applicable to liquids. Thus liquid correlations tend to be more empirical than the equivalent ones for the gas phase.

A relatively simple procedure for estimating the viscosity of a liquid is to assume the equation presented earlier for gases under pressure also applies. However, when applying the Jossi et al. equation (Eqn. 9), use the liquid density. This provides estimates that are in the range of 25%, which is often of sufficient accuracy for many applications.

PROPERTIES OF ACID GAS MIXTURES

Thermodynamic Properties

The equations of state mentioned earlier are powerful tools for dealing with mixtures. All of the thermodynamic properties for mixtures are easily calculated with an equation of state and this method approach handles the phases intrinsically.

All of the thermodynamic properties of the gas phase should be calculated using an equation of state. This is typically true for the liquid as well, with the exception of the density. The commonly used equations of state do a poor job of estimating liquid density. Often the liquid density from the equation of state is rejected in favor of one from the more accurate empirical expression such as the COSTALD equation. In this case the following equation can be used:

$$v_{mix} = \sum_{i=1}^{NC} x_i v_i^{pure} \tag{11}$$

where: v_{mix} – molar volume of the mixture, m³/kmol

v_i^{pure} – molar volume of pure i, m³/kmol

x_i – mole fraction of component I

NC – number of components

The density is then calculated from:

$$\rho = \frac{M}{v} \tag{12}$$

The Eqn (11) is an approximation of the thermodynamically exact equation:

$$v_{mix} = \sum_{i=1} x_i \overline{v}_i \tag{13}$$

where: $\overline{v}_i$ – partial molar volume of component i, m³/kmol

However, the problem in applying this rigorous equation is obtaining the partial molar volumes. These are mixture properties and are not tabulated in standard reference books. The reader should consult a textbook on chemical thermodynamics for a detailed discussion of this equation.

Corresponding States

To apply the principle of corresponding states to a mixture one must employ a mixing rule. A mixing rule is a method to estimate the critical properties of the mixture for use with the correlation (*i.e.*, not the true critical point). The simplest and most widely used is Kay's rule (often referred to as the pseudocritical temperature and pseudocritical pressure):

$$pT_C = \sum_i x_i T_{Ci} \tag{14}$$

$$pP_C = \sum_i x_i P_{Ci} \tag{15}$$

Note, these values are not meant to be the actual critical properties of the fluid, they are used simply to estimate the properties of the fluid based on the corresponding states principle.

Reduced properties are then calculated for the mixture based on the pseudocritical properties.

Transport Properties

For the transport properties we must resort to some other method. These methods are usually specific to the phase, but there are those that are applicable regardless of the phase.

For example, the viscosity of low pressure gases can be estimated by the following combining rule:

$$\mu = \sum_i \frac{y_i \mu_i}{\sum_j y_i \phi_{ij}} \tag{16}$$

where: μ_i – pure component viscosity

y_i – mole fraction of component i

ϕ_{ij} – represents the interaction between component i and component j.

Most correlations use this approach and the problem becomes one of estimating the parameters ϕ_{ij} For example, Wilke (Reid et al., 1987) gives the following expression:

$$\phi_{ij} = \frac{\left[1 + \left(\mu_i/\mu_j\right)^{1/2}\left(M_i/M_j\right)^{1/4}\right]^2}{\left[8\left(1 + M_j/M_i\right)\right]^{1/2}} \tag{17}$$

where: M – molar mass of the component, kg/kmol

On the other hand, for liquids the commonly used mixing rule is logarithmic in the pure component viscosity:

$$\ln \mu = \sum_i x_i \ln \mu_i + \sum_i \sum_j x_i x_j \eta_{ij} \tag{18}$$

where: x_i – mole fraction of component i

η_{ij} – interaction parameter, which requires some experimental data

for the mixture

Unfortunately, no binary viscosity data exist for acid gas mixtures. And unlike gas mixtures, there is no good correlation available for the interaction parameters. Although not true for all systems, it is probably safe to set η_{ij} equal to zero in this case. The liquid mixture equation reduces to:

$$\ln \mu = \sum_i x_i \ln \mu_i \tag{19}$$

A better approach is to calculate the viscosity of the mixture by first assuming that it is a low pressure gas. This viscosity is then corrected using a corresponding states method, which requires the density of the mixture.

Similar expressions are available for the thermal conductivity of a gas mixture or a liquid mixture.

Word of Caution

A significant problem has been overlooked in many of the mixture correlations presented above. Many of the mixture correlations require the pure component property at the temperature and pressure of interest. For example, the specific volume of a liquid mixture can be calculated using the following equation, which was presented earlier:

$$v_{mix} = \sum_{i=1} x_i v_i^{pure}$$

How do we apply this equation if all of the substances are not liquids? For example, consider a mixture containing 10% carbon dioxide and 90% hydrogen sulfide at 50°C and 7 MPa. At these conditions the mixture is a liquid as is H_2S, but pure CO_2 is not. At this temperature, carbon dioxide is supercritical and behaves like a gas regardless of the pressure. What value should be used for the specific volume of pure CO_2 in the above equation in order to obtain the specific volume of the

mixture? To avoid this problem we need some mixture information from which we could extract a mixture-specific pure pseudo-property. Such a problem should not arise when using either an equation of state or a corresponding states approach. With these methods the mixture properties are calculated directly and not as a combination of the pure component properties.

A similar problem can arise in any of the correlations that relate the properties of a mixture to the pure component properties at the temperature and pressure of the mixture. In this module these included the viscosity and thermal conductivity of both liquids and gases.

EFFECT OF HYDROCARBONS

In this section we will examine the effect of hydrocarbons, specifically methane, have on the physical properties of acid gases. The effect on the vapor pressure (i.e., the vapor-liquid equilibrium) has been discussed elsewhere.

Methane is the most common hydrocarbon in acid gas mixtures. Large quantities of other hydrocarbons are probably indicative of problems with the amine plant and should be addressed. For example, foaming will cause carry-over of the hydrocarbons into the stripper. In the regeneration of the amine, the hydrocarbons will end up in the acid gas.

All of the equations presented earlier for predicting the properties of mixtures can be used if methane is in the mix. However some general comments can be made.

First, methane is much less dense than the acid gas components. With respect to the density of the gas, methane has a lower molar mass than the acid gas components. This means that an acid gas mixture that contains some methane with have a lower specific gravity, and hence density, than a mixture without methane.

In the liquid phase methane is less dense as well. An acid gas mixture in the liquid phase that contains some methane will be less dense than one without.

The effect of methane on the viscosity is a little more subtle. From Fig. 3 it can be seen that the low pressure viscosity of methane is less than that for the acid gas components. Thus we would expect that an acid gas mixture containing methane would be less viscous at low pressure than one without. Correcting the viscosity for pressure requires the density of the mixture. Since acid gas mixtures are less dense when they contain methane, then the correction is smaller. Therefore we can

conclude that acid gas mixtures containing methane will be less viscous than those that do not. The exact magnitude of this effect can only be determined by applying the equations presented earlier.

IN SUMMARY

Hydrogen sulfide and carbon dioxide are the key components in acid gas, and water and methane are important secondary components. The design engineer must be able to estimate the properties of these substances in order to design the injection scheme. In this paper some properties were presented along with methods for estimating them.

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Table 1   Some Properties of Hydrogen Sulfide, Carbon Dioxide, Methane, and Water

	H_2S	CO_2	CH_4	H_2O
Molar Mass, kg/kmol	34.082	44.010	16.043	18.015
Critical Temperature, K	373.5	304.2	190.6	647.1
Critical Temperature, °C	100.4	31.1	-82.6	374.0

Critical Pressure, MPa	8.963	7.382	4.604	22.055
Critical Volume, m³/kmol	0.0985	0.0940	0.0993	0.0560
Critical Density, kg/m³	346	468	162	322
Critical Compressibility, ($P_C v_C / RT_C$)	0.284	0.274	0.288	0.229
Triple Point Temperature, K	187.7	216.6	90.7	273.16
Triple Point Temperature, °C	-86.5	-56.6	-182.5	0.01
Triple Point Pressure, kPa	23.2	518	11.7	0.611
Normal Boiling Point, K	212.8	$-^{\dagger}$	111.7	373.2
Normal Boiling Point, °C	-60.4	$-^{\dagger}$	-161.5	100.0
Melting Point, K	187.7	$-^{\dagger}$	90.7	273.2
Melting Point, °C	-85.5	$-^{\dagger}$	-182.5	0.0
Enthalpy of Vaporization at T_b, kJ/mol	18.68	$-^{\dagger}$	8.20	40.65
Enthalpy of Vaporization at 25°C, kJ/mol	14.08	5.32	–	43.98
Gross Heating Value (Gas), MJ/m³	23.8	$-^{\ddagger}$	37.7	$-^{\ddagger}$
Specific Gravity of Gas[*], unitless	1.177	1.520	0.535	0.622

† - carbon dioxide sublimes at 194.7 K and 101.325 kPa

‡ - carbon dioxide and water are non-combustible

* - relative to air

Table 2 Properties of Saturated Liquid Carbon Dioxide

Temp. (°C)	Vapor Pressure (MPa)	Density (kg/m³)	Heat Capacity (kJ/kg•K)	Viscosity (cp)	Thermal Conduct. (W/m•K)
-10	2.649	983	2.29	0.1202	0.1218
-5	3.046	957	2.40	0.1113	0.1158
0	3.485	928	2.54	0.1028	0.1097
5	3.969	897	2.73	0.0904	0.1035
10	4.502	862	3.01	0.0794	0.0972
15	5.086	821	3.44	0.0702	0.0907
20	5.728	773	4.26	0.0612	0.0837
25	6.432	711	6.41	0.5016	0.756
30	7.211	595	33.21	0.0413	0.0628
31.1	7.382	468	∞	0.0322	0.0508

Table 3 Properties of Saturated Vapor Carbon Dioxide

Temp. (°C)	Vapor Pressure (MPa)	Density (kg/m³)	Heat Capacity (kJ/kg•K)	Viscosity (µp)	Thermal Conduct. (W/m•K)
-10	2.649	71.3	1.55	149	0.0177
-5	3.046	83.5	1.71	152	0.0188
0	3.485	97.8	1.92	155	0.0200
5	3.969	114.8	2.21	162	0.0214
10	4.502	135.4	2.62	172	0.0231
15	5.086	161	3.29	183	0.0250
20	5.728	194	4.57	198	0.0279
25	6.432	243	7.97	218	0.0319
30	7.211	344	47.5	267	0.0402
31.1	7.382	468	∞	322	0.0508

Note: 1 cp = 0.01 poise = 10 000 µp = 0.001 kg/m•s = 0.001 Pa•s

Table 4   Properties of Saturated Liquid Hydrogen Sulfide

| Temp. (°C)	Vapor Pressure (MPa)	Density (kg/m³)	Heat Capacity (kJ/kg•K)	Viscosity (cp)	Thermal Conduct. (W/m•K)
-10	0.754	856	2.02	0.167	0.198
0	1.024	835	2.05	0.152	0.181
10	1.358	813	2.10	0.139	0.165
20	1.767	790	2.18	0.127	0.150
30	2.58	465	2.29	0.116	0.137
40	2.841	738	2.44	0.104	0.124
50	3.525	710	2.64	0.0934	0.112
60	4.320	677	2.93	0.0819	0.100
70	5.234	640	3.37	0.0700	0.082
80	6.277	596	4.14	0.0575	0.067
90	7.459	539	5.81	0.0440	0.053
100.4	8.963	346	∞	0.0255	0.030

Table 5   Properties of Saturated Vapor Hydrogen Sulfide

Temp. (°C)	Vapor Pressure (MPa)	Density (kg/m³)	Heat Capacity (kJ/kg•K)	Viscosity (μp)	Thermal Conduct. (W/m•K)
-10	0.754	12.8	1.15	113	0.0124
0	1.024	17.1	1.19	121	0.0132
10	1.358	22.4	1.23	124	0.0140
20	1.767	28.9	1.29	127	0.0148
30	2.58	37.0	1.36	133	0.0156
40	2.841	46.7	1.45	141	0.0164
50	3.525	58.7	1.56	149	0.0173
60	4.320	73.6	1.73	155	0.0182
70	5.234	92.3	1.98	161	0.0192
80	6.277	116.6	2.42	169	0.021
90	7.459	150.5	3.43	189	0.022
100.4	8.963	346	∞	255	0.030

**Table 6   Ideal Gas Heat Capacity Correlation Coefficients
for Use with Eqn. (3)**

	A	B	C	D
H_2S	3.194E+1	1.436E-3	2.432E-5	-1.176E-8
CO_2	1.980E+1	7.344E-2	-5.602E-5	1.715E-8
CH_4	1.925E+1	5.213E-2	1.197E-5	-1.132E-8
H_2O	3.224E+01	1.924E-3	1.055E-5	-3.596E-9

Fig. 1 Density of Saturated Carbon Dioxide
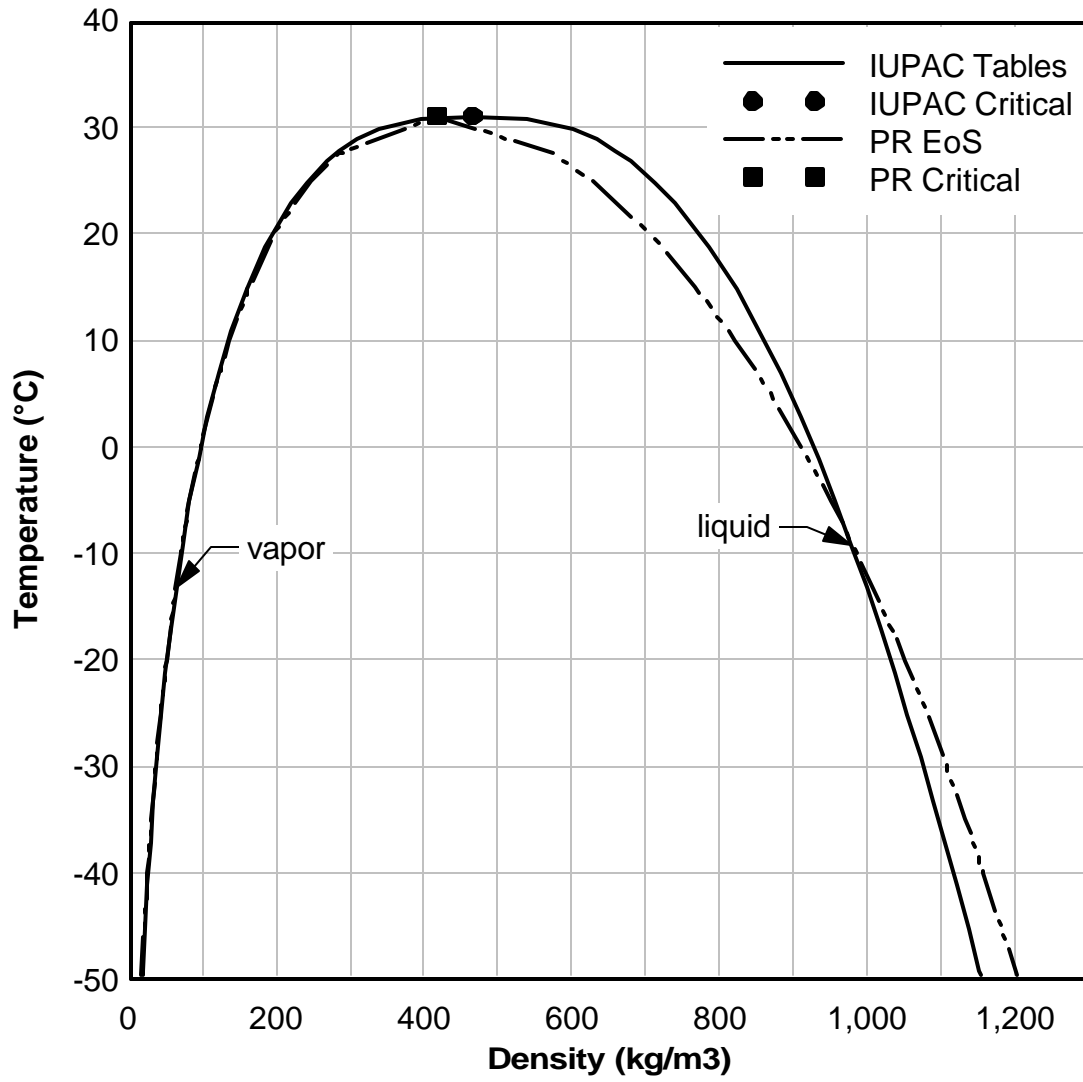
Fig. 2 Density of Saturated Hydrogen Sulfide
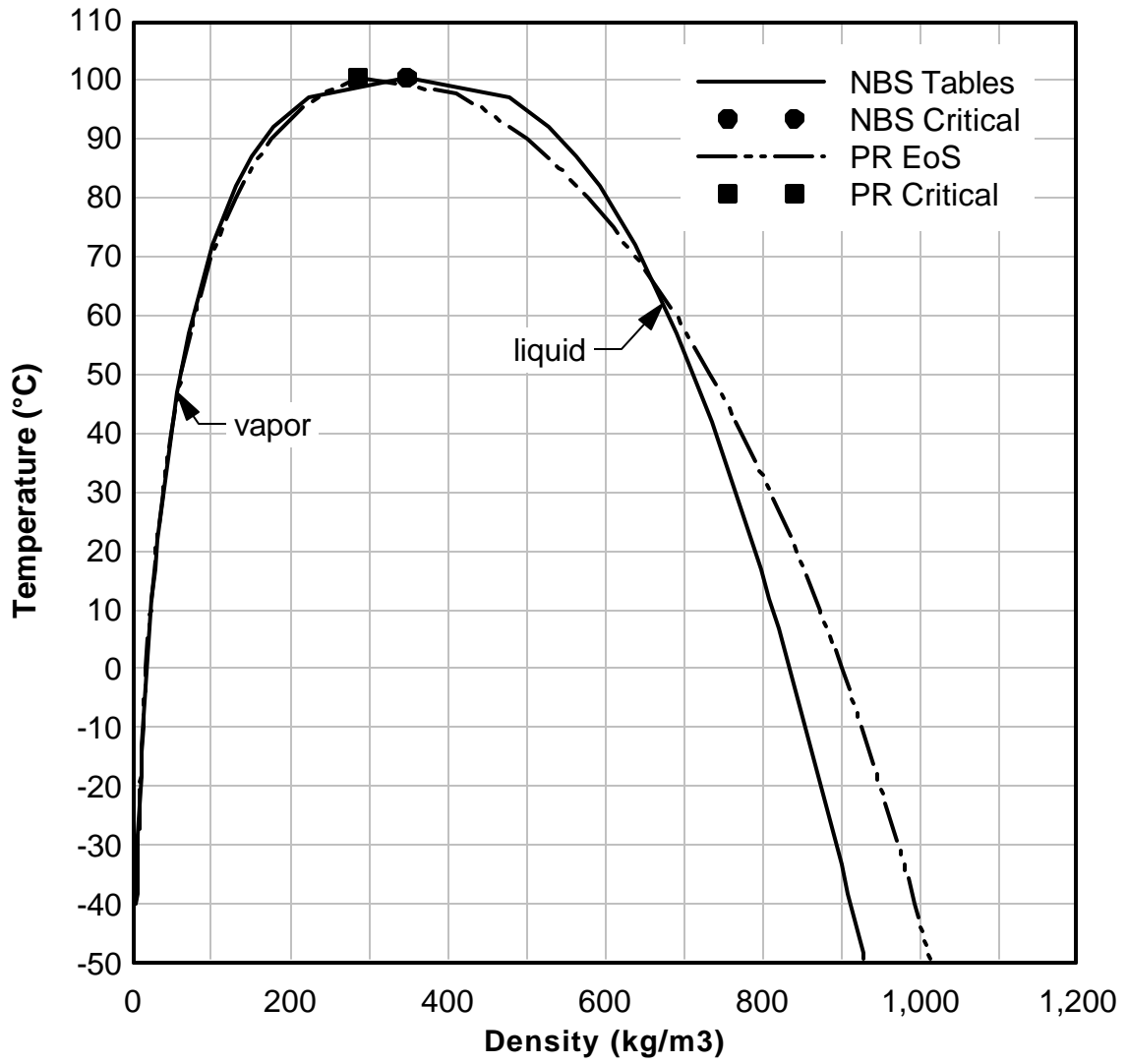
Fig. 3   Viscosities of Several Gases at Low Pressure