critical constants were found to depend on the molecular mass, m, and temperature in a simple manner. The effective critical temperature and effective critical pressure are given by

F

$$T_e = \frac{T_e^\circ}{1 + \frac{c_1}{mT}} \tag{18}$$

$$P_c = \frac{P_c^{\circ}}{1 + \frac{c_2}{mT}} \tag{19}$$

where

$$c_1 = 21.8^\circ \text{ K.}$$
 (20)
 $c_2 = 44.2^\circ \text{ K.}$ (21)

 T_c° and P_c° are, respectively, the classical critical temperature and pressure—i.e., the effective critical temperature and pressure in the limit of high temperature. Table III gives T_c° and P_c° for nine quantum gases.

For mixtures containing one or more of the quantum gases, Equations 8 through 12 are used, except that T_{ci} and P_{ci} are given by Equations 18 and 19; further, T_{cij} and P_{cij} are given by

$$T_{eij} = \frac{\sqrt{T_{eij}^{\circ} T_{ejj}^{\circ}} (1 - k_{ij})}{1 + \frac{c_1}{m_{ij}T}}$$

$$P_{eij} = \frac{P_{eij}^{\circ}}{c_0}$$
(22)

$$1 + \frac{c_2}{m_{41}T}$$

$$P_{c_{ij}}^{\circ} = \frac{z_{c_{ij}}^{\circ} R \sqrt{T_{c_{ii}}^{\circ} T_{c_{jj}}^{\circ}} (1 - k_{ij})}{v_{c_{ij}}^{\circ}}$$
(24)

$$v_{c_{ij}}^{\circ}{}^{1/3} = \frac{1}{2} \left(v_{c_i}^{\circ}{}^{1/3} + v_{c_j}^{\circ}{}^{1/3} \right)$$
(25)

$$z_{c_{ij}}^{\circ} = 0.291 - 0.08 \left(\frac{\omega_i + \omega_j}{2}\right) \tag{26}$$

$$\frac{1}{m_{ij}} = \frac{1}{2} \left(\frac{1}{m_i} + \frac{1}{m_j} \right)$$
(27)

For all quantum gases, Ω_a and Ω_b are, respectively, 0.4278 and 0.0867, and ω (effective) is zero. Values of v_c° for quantum gases are calculated from the relation $v_c^{\circ} = 0.291 RT_c^{\circ} / P_c^{\circ}$; they are listed in Table III.

Figure 7 shows experimental and calculated compressibility factors for the two quantum gases, hydrogen (Johnston and White, 1948) and helium (Mann, 1962) at cryogenic temperatures. Calculated results were obtained from the Redlich-Kwong equation using effective critical constants. Good agreement is obtained over the entire temperature and pres-

Table III.	Classical Critical	Constants for Q	uantum Gases
	$T_c^{\circ}, \circ K.$	Pe°, Atm.	vc°, Cc./ Gram Mole
Ne	45.5	26.9	40.3
He ⁴	10.47	6.67	37.5
He ³	10.55	5.93	42.6
H ₂	43.6	20.2	51.5
HD	42.9	19.6	52.3
HT	42.3	19.1	52.9
D_2	43.6	20.1	51.8
DT	43.5	20.3	51.2
T_2	43.8	20.5	51.0

sure range, including the isotherms very close to the critical. The slightly high compressibility factors near the critical point are due to an inherent limitation of the Redlich-Kwong equation which gives $z_c = 1/3$ for all gases when $\Omega_a = 0.4278$ and $\Omega_b = 0.0867$.

Figure 8 shows experimental and calculated fugacity co-







Figure 8. Fugacity coefficients of methane in hydrogen at saturation

 $k_{12} = 0.03$ obtained from second virial coefficient data

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125

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:oef-(1)-

.0

0.9

D.8

0.7

0.6

0.5

coef-

hane

z

