VBA – An Exercise for Practicing Programming in the ChE Curriculum

by

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Introduction

A programming exercise is described by Shacham et al (1) which is carried out in Matlab (2). The exercise involves the analytical solution of the Redlich-Kwong equation for the compressibility factor and the consequent calculation of molar volume, fugacity coefficient, isothermal enthalpy and entropy departure. The authors indicate that other programming languages (such as C or C++) can also be used. Since Matlab is widely used in academia and is often taught as ***the*** programming language, such a choice is reasonable.

In industry, however, languages such as Matlab may not always be available or accessible. More likely Excel would be available and so teaching and carrying out such an exercise in the macro language of Excel, Visual Basic for Applications (VBA), is a viable alternative (3). The undergraduate chemical engineering student is generally familiar with Excel and anecdotal evidence indicates the student gravitates toward its use after exposure to other languages/systems(4).

The VBA Program

The VBA program looks very similar to the Matlab program. However, the main program (the spreadsheet) is particularly simple in Excel.

There are some small differences, however between the Matlab and VBA languages in this case. In VBA the sign function is sgn, sqr is the square root and there is no max or acos function in VBA but there is in the Excel spreadsheet. In VBA to find the maximum of a series of numbers, application.max is used and application.acos is used to find the arccosine. In VBA there is also no case differences so bb is used for b and rr is used for r to be different from B and R(see Figure 1 in Reference (1)).

As in Matlab, a function procedure, RKfunc (1), is written which is called directly from the spreadsheet. Depending on what property is desired, a Kode argument is included in the argument list of RKfunc (Figure 1).

Kode = 1 Compressibility Factor
Kode = 2 Enthalpy Departure, $\Delta H/Tc$, J/mol-K
Kode = 3 Entropy Deaparture, ΔS, J/mol-K
Kode = 4 Fugacity Coefficient

Four separate sheets in Excel are set up and the same function procedure is called from each sheet.

The Spreadsheet

Figures 2 to 5 show the spreadsheets used for calculating the compressibility, isothermal enthalpy departure, the isothermal pressure departure and fugacity coefficient as a function of reduced pressure and temperature.

The function procedure RKfunc is invoked at each table entry as:

```
= RKfunc (Tc, Pc, Tr, Pr, Kode)
```

For the entry at Pr = 5 and Tr = 1.2 the entry would be

```
= RKfunc ($B$5,$B$6, F$9,  $A35,  $B$7)
```

where B5 = Location of Tc
B6 = Location of Pc
F$9 = Location of Tr
$A35 = Location of Pr
B7 = Location of Kode

Comparison to Charts

Table 1 compares the results of the VBA/spreadsheet program (Figure 6) to that given in classical charts (5). Since the classical charts are based on the theory of corresponding states and not on the Redlich Kwong Equation of State, the differences are not surprising (6).

	Tr	Pr	VBA (Spreadsheet)	Chart
Compressibility	1.40	1.51	.82	.84
Enthalpy Departure J/(mol-K)	1.23	1.37	9.65	10.66
Entropy Departure J/(mol K)	1.23	1.37	5.66	6.23
Fugacity Coefficient	1.70	1.49	.92	.94

Table 1
VBA Comparison to Charts

Conclusions

The overall programming effort for this exercise in Matlab and VBA is about the same, though the spreadsheet's main program is somewhat simpler. Which programming language is used in practice, however, is a function of program availability, cost and user training.

References

1. Shacham, M, Brauner, N. and Cutlip, M., "An Exercise for Practicing Programming in the ChE Curriculum", *Chemical Engineering Education* vol 37, No. 2, Spring 2003 p. 148

2. MATLAB is a trademark of The Math Works, Inc http://www.mathworks.com

3. Walkenbach, John, *Microsoft Excel 2000 Power Programming with VBA* IDG Books Worldwide, Inc., Foster City, Ca 1999

4. Misovich, M. J. “Making Phase Equilibrium More User-Friendly”, *Chemical Engineering Education*, Fall 2002 36, 4 p 284

5. Hougen, O. A. and Watson, K. M. *Chemical Process Principles Part Two Thermodynamics*, John Wiley (New York) 1948 pages 490,496,499,621

6. Peress, J. “Working With Non-Ideal Gases, *Chemical Engineering Progress*, March 2003, p 39.

```
Option Explicit
Public Function RKfunc(Tc, Pc, Tr, Pr, Kode)
'  Pc in pascals
'  Tc in kelvins
'  Tr  Reduced Temperature
'  Pr  Reduced Pressure

'  Kode = 1   z
'  Kode = 2   Hdep
'  Kode = 3   Sdep
'  Kode = 4   fcoeff

Dim a, bb, Asqr, B, R, q, f, g, C As Single

Dim D, E1, E, z As Single
Dim psii, zv(3) As Single

Dim P, T, V  As Single
Dim Hdep, Sdep, f_coeff

Dim rr As Single
Dim E1x, E1y

Dim zz, zzz, s, ss As Single

' R in J/mole/K
R = 8.3143

a = 0.42747 * R ^ 2 * Tc ^ (5 / 2) / Pc
bb = 0.08664 * R * Tc / Pc

Asqr = 0.42747 * Pr / (Tr ^ 2.5)
B = 0.08664 * Pr / Tr
rr = Asqr * B
q = B ^ 2 + B - Asqr
f = (-3 * q - 1) / 3
g = (-27 * rr - 9 * q - 2) / 27
C = (f / 3) ^ 3 + (g / 2) ^ 2

If C > 0 Then

D = ((-g / 2 + Sqr(C)) ^ (1 / 3))
E1 = (-g / 2 - Sqr(C))

E = ((Sgn(E1) * (Abs(E1)) ^ (1 / 3)))

z = (D + E + 1 / 3)

Else

psii = (Application.Acos(Sqr((g ^ 2 / 4) / (-f ^ 3 / 27))))

zv(1) = (2 * Sqr(-f / 3) * Cos((psii / 3)) + 1 / 3)
zv(2) = (2 * Sqr(-f / 3) * Cos((psii / 3) + 2 * 3.14159 * 1 / 3) + 1 / 3)
zv(3) = (2 * Sqr(-f / 3) * Cos((psii / 3) + 2 * 3.14159 * 2 / 3) + 1 / 3)
```

```
z = Application.Max(zv(1), zv(2), zv(3))

End If

P = Pr * Pc
T = Tr * Tc
V = z * R * T / P
Hdep = (3 * a / (2 * bb * R * T ^ 1.5)) * Log(1 + bb / V) - (z - 1)

'Put in Standard Form
Hdep = Hdep * R * T
Hdep = Hdep / Tc


Sdep = (a / (2 * bb * R * T ^ 1.5)) * Log((1 + bb / V)) - Log(z - P * bb / (R *
T))
'Put in Standard Form
Sdep = Sdep * R

f_coeff = Exp(z - 1 - Log(z * (1 - bb / V)) - a / (bb * R * T ^ 1.5) * Log(1 +
bb / V))

If Kode = 1 Then RKfunc = z
If Kode = 2 Then RKfunc = Hdep
If Kode = 3 Then RKfunc = Sdep
If Kode = 4 Then RKfunc = f_coeff


End Function
```

Figure 1
Public Function RKfunc

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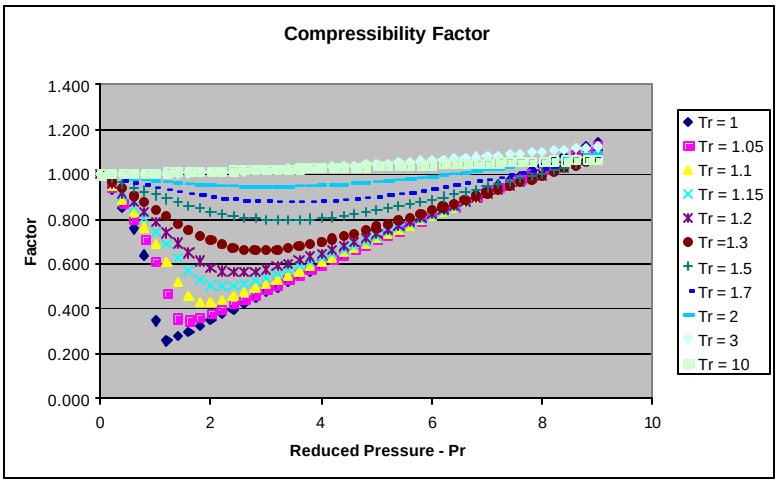
Water

Figure 2 Compressibility Factor

Tc 647.4 Kelvins
Pc 22119248 Pascals
Kode 1

	<==========Tr==========										
Pr	1	1.05	1.1	1.15	1.2	1.3	1.5	1.7	2	3	10
0	1.000	1	1	1	1	1	1	1	1	1	1
0.2	0.929	0.9387	0.9469	0.9538	0.9596	0.9688	0.9807	0.9877	0.9937	1.0004	1.0015
0.4	0.849	0.8721	0.8905	0.9056	0.918	0.9372	0.9616	0.9758	0.9878	1.0008	1.0029
0.6	0.757	0.7983	0.83	0.8549	0.875	0.9054	0.9429	0.9643	0.9822	1.0015	1.0044
0.8	0.639	0.7137	0.7641	0.8015	0.8307	0.8735	0.9248	0.9534	0.977	1.0022	1.0059
1	0.347	0.6101	0.6911	0.7451	0.7852	0.8418	0.9072	0.943	0.9722	1.0031	1.0073
1.2	0.258	0.4666	0.6093	0.6859	0.7389	0.8105	0.8905	0.9332	0.9678	1.0041	1.0088
1.4	0.277	0.3575	0.5219	0.6256	0.693	0.7803	0.8746	0.9241	0.9639	1.0052	1.0103
1.6	0.300	0.3497	0.4559	0.5697	0.6496	0.7518	0.8598	0.9157	0.9604	1.0064	1.0118
1.8	0.324	0.3618	0.4318	0.5281	0.6123	0.7259	0.8462	0.9081	0.9573	1.0078	1.0133
2	0.349	0.3796	0.4313	0.5061	0.5846	0.7035	0.834	0.9014	0.9547	1.0093	1.0148
2.2	0.374	0.3998	0.4409	0.4998	0.568	0.6856	0.8234	0.8954	0.9525	1.0109	1.0162
2.4	0.399	0.4211	0.4553	0.5033	0.5612	0.6725	0.8145	0.8904	0.9508	1.0126	1.0177
2.6	0.423	0.443	0.4722	0.5124	0.5618	0.6642	0.8073	0.8863	0.9496	1.0145	1.0192
2.8	0.448	0.4651	0.4905	0.525	0.5675	0.6605	0.8019	0.8831	0.9489	1.0165	1.0207
3	0.472	0.4874	0.5097	0.5397	0.5767	0.6606	0.7983	0.8808	0.9486	1.0185	1.0222
3.2	0.497	0.5098	0.5294	0.5557	0.5883	0.6639	0.7963	0.8794	0.9487	1.0207	1.0237
3.4	0.521	0.5321	0.5494	0.5727	0.6016	0.6698	0.796	0.879	0.9494	1.023	1.0252
3.6	0.544	0.5544	0.5697	0.5904	0.6161	0.6777	0.7973	0.8794	0.9504	1.0254	1.0267
3.8	0.568	0.5766	0.5901	0.6085	0.6315	0.6872	0.7999	0.8806	0.9519	1.0279	1.0282
4	0.592	0.5988	0.6105	0.6269	0.6475	0.698	0.8037	0.8827	0.9538	1.0305	1.0297
4.2	0.615	0.6208	0.631	0.6455	0.6639	0.7097	0.8088	0.8855	0.9561	1.0333	1.0313
4.4	0.638	0.6428	0.6515	0.6643	0.6808	0.7223	0.8148	0.889	0.9588	1.0361	1.0328
4.6	0.661	0.6646	0.672	0.6831	0.6978	0.7355	0.8217	0.8931	0.9619	1.039	1.0343
4.8	0.684	0.6864	0.6924	0.7021	0.7151	0.7492	0.8293	0.8979	0.9654	1.042	1.0358
5	0.707	0.708	0.7128	0.721	0.7326	0.7633	0.8376	0.9032	0.9692	1.0451	1.0373
5.2	0.730	0.7296	0.7331	0.74	0.7501	0.7777	0.8466	0.909	0.9733	1.0482	1.0388
5.4	0.752	0.7511	0.7534	0.759	0.7677	0.7924	0.856	0.9154	0.9777	1.0515	1.0404
5.6	0.775	0.7724	0.7736	0.778	0.7854	0.8074	0.8659	0.9221	0.9825	1.0549	1.0419
5.8	0.797	0.7937	0.7937	0.797	0.8031	0.8225	0.8762	0.9293	0.9875	1.0583	1.0434
6	0.820	0.8149	0.8138	0.8159	0.8209	0.8377	0.8868	0.9368	0.9927	1.0618	1.045
6.2	0.842	0.836	0.8338	0.8348	0.8386	0.8531	0.8978	0.9447	0.9983	1.0654	1.0465
6.4	0.864	0.857	0.8538	0.8537	0.8564	0.8686	0.909	0.9528	1.004	1.0691	1.048
6.6	0.886	0.878	0.8737	0.8726	0.8742	0.8842	0.9204	0.9613	1.01	1.0728	1.0496
6.8	0.908	0.8989	0.8935	0.8914	0.8919	0.8998	0.9321	0.97	1.0162	1.0766	1.0511
7	0.929	0.9196	0.9133	0.9101	0.9097	0.9155	0.9439	0.9789	1.0226	1.0805	1.0526
7.2	0.951	0.9404	0.933	0.9288	0.9274	0.9312	0.9559	0.988	1.0292	1.0845	1.0542
7.4	0.973	0.961	0.9527	0.9475	0.9451	0.9469	0.968	0.9973	1.0359	1.0885	1.0557
7.6	0.994	0.9816	0.9723	0.9661	0.9627	0.9627	0.9803	1.0069	1.0428	1.0926	1.0573
7.8	1.016	1.0021	0.9918	0.9847	0.9804	0.9785	0.9926	1.0164	1.0499	1.0967	1.0588
8	1.037	1.0225	1.0113	1.0033	0.998	0.9943	1.0051	1.0276	1.0571	1.1009	1.0604
8.2	1.059	1.0429	1.0307	1.0218	1.0156	1.0101	1.0177	1.0363	1.0644	1.1052	1.0619
8.4	1.080	1.0632	1.0501	1.0402	1.0331	1.0259	1.0303	1.0462	1.0719	1.1095	1.0635
8.6	1.101	1.0834	1.0694	1.0586	1.0507	1.0417	1.043	1.0564	1.0795	1.1138	1.065
8.8	1.122	1.1036	1.0887	1.077	1.0682	1.0576	1.0557	1.0667	1.0871	1.1183	1.0666
9	1.143	1.1238	1.1079	1.0953	1.0856	1.0734	1.0685	1.077	1.0949	1.1227	1.0681



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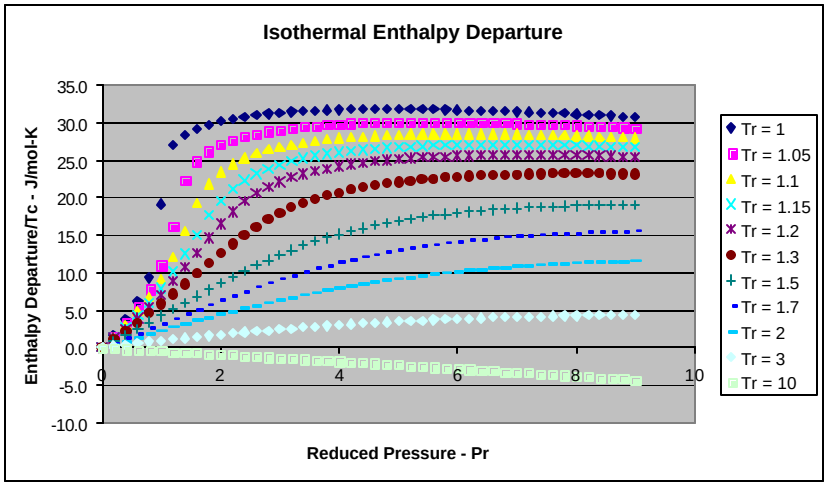
Water

Figure 3 Enthalpy Departure

Tc	647.4	Kelvins
Pc	22119248	Pascals
Kode	2	

<=========Tr=========>

Pr	1	1.05	1.1	1.15	1.2	1.3	1.5	1.7	2	3	10
1E-08	0.000	5E-08	4.6E-08	4E-08	4E-08	3.6E-08	3E-08	2E-08	2E-08	1E-08	2E-09
0.2	1.731	1.582	1.45324	1.3408	1.2416	1.07499	0.8297	0.6585	0.4822	0.1956	-0.088
0.4	3.717	3.3471	3.0407	2.7812	2.558	2.19228	1.6717	1.318	0.9598	0.3867	-0.177
0.6	6.113	5.37348	4.8037	4.3437	3.961	3.35471	2.5249	1.9774	1.4322	0.5731	-0.265
0.8	9.343	7.81172	6.80689	6.0581	5.4647	4.56446	3.3876	2.6351	1.8987	0.7548	-0.354
1	19.159	11.0216	9.1573	7.9639	7.0842	5.82231	4.2577	3.2897	2.3586	0.9318	-0.444
1.2	27.013	16.2124	12.0339	10.108	8.8325	7.12636	5.1321	3.9394	2.8111	1.104	-0.534
1.4	28.376	22.4238	15.6172	12.52	10.711	8.47028	6.0071	4.5824	3.2555	1.2714	-0.624
1.6	29.202	24.9087	19.2964	15.128	12.69	9.84102	6.8782	5.2166	3.6912	1.4341	-0.715
1.8	29.780	26.2264	21.8563	17.628	14.681	11.2168	7.74	5.8399	4.1173	1.5919	-0.806
2	30.215	27.0932	23.4669	19.677	16.545	12.5675	8.5867	6.4503	4.5334	1.7449	-0.897
2.2	30.554	27.7214	24.5597	21.215	18.162	13.8578	9.4121	7.0456	4.9386	1.8931	-0.989
2.4	30.824	28.2016	25.3555	22.362	19.493	15.0556	10.21	7.6238	5.3326	2.0365	-1.081
2.6	31.042	28.5807	25.9637	23.237	20.566	16.1386	10.975	8.1831	5.7148	2.1751	-1.173
2.8	31.220	28.8864	26.444	23.924	21.431	17.0982	11.701	8.7219	6.0847	2.3089	-1.266
3	31.366	29.1362	26.8318	24.474	22.135	17.937	12.386	9.2386	6.442	2.438	-1.359
3.2	31.484	29.3422	27.1499	24.924	22.714	18.6649	13.026	9.7322	6.7863	2.5623	-1.452
3.4	31.581	29.5128	27.4137	25.296	23.196	19.2947	13.622	10.202	7.1175	2.6819	-1.546
3.6	31.658	29.6542	27.6339	25.607	23.601	19.8397	14.172	10.647	7.4354	2.7968	-1.64
3.8	31.720	29.771	27.8184	25.869	23.944	20.3119	14.677	11.068	7.7399	2.9071	-1.734
4	31.766	29.8671	27.9734	26.09	24.235	20.7221	15.143	11.465	8.031	3.0128	-1.829
4.2	31.801	29.9452	28.1032	26.279	24.484	21.0791	15.564	11.837	8.3087	3.1139	-1.924
4.4	31.824	30.0078	28.2116	26.438	24.698	21.3906	15.95	12.185	8.5732	3.2106	-2.02
4.6	31.838	30.0566	28.3014	26.574	24.881	21.6628	16.301	12.511	8.8245	3.3028	-2.115
4.8	31.842	30.0934	28.375	26.688	25.039	21.9008	16.619	12.815	9.063	3.3906	-2.211
5	31.839	30.1193	28.4343	26.784	25.173	22.1091	16.908	13.097	9.2889	3.4741	-2.307
5.2	31.829	30.1356	28.4809	26.864	25.288	22.2913	17.169	13.359	9.5024	3.5534	-2.404
5.4	31.811	30.1432	28.5163	26.93	25.385	22.4505	17.405	13.602	9.7038	3.6284	-2.501
5.6	31.788	30.1428	28.5415	26.982	25.467	22.5892	17.619	13.826	9.8936	3.6993	-2.598
5.8	31.760	30.1353	28.5575	27.024	25.535	22.7097	17.811	14.033	10.072	3.7661	-2.695
6	31.726	30.1213	28.5652	27.055	25.591	22.8138	17.984	14.224	10.239	3.8289	-2.793
6.2	31.687	30.1012	28.5653	27.077	25.636	22.9032	18.14	14.399	10.396	3.8877	-2.891
6.4	31.645	30.0755	28.5585	27.09	25.67	22.9794	18.279	14.56	10.543	3.9427	-2.99
6.6	31.598	30.0448	28.5453	27.096	25.695	23.0435	18.403	14.707	10.679	3.9938	-3.088
6.8	31.547	30.0093	28.5263	27.094	25.712	23.0967	18.514	14.842	10.806	4.0413	-3.187
7	31.493	29.9694	28.5018	27.086	25.721	23.1398	18.611	14.964	10.924	4.085	-3.287
7.2	31.436	29.9255	28.4724	27.072	25.723	23.1737	18.697	15.075	11.033	4.1252	-3.386
7.4	31.375	29.8777	28.4383	27.053	25.718	23.1991	18.772	15.174	11.134	4.1618	-3.486
7.6	31.312	29.8263	28.3999	27.028	25.708	23.2168	18.838	15.263	11.227	4.195	-3.586
7.8	31.246	29.7716	28.3574	26.998	25.691	23.2273	18.893	15.347	11.311	4.2247	-3.686
8	31.177	29.7138	28.3112	26.964	25.67	23.2311	18.94	15.38	11.389	4.2512	-3.787
8.2	31.106	29.653	28.2614	26.926	25.644	23.2286	18.979	15.475	11.459	4.2744	-3.888
8.4	31.033	29.5894	28.2083	26.884	25.613	23.2204	19.01	15.537	11.522	4.2944	-3.989
8.6	30.957	29.5233	28.152	26.838	25.578	23.2069	19.034	15.582	11.579	4.3114	-4.09
8.8	30.880	29.4546	28.0928	26.789	25.538	23.1882	19.052	15.622	11.63	4.3252	-4.192
9	30.800	29.3836	28.0309	26.736	25.496	23.1649	19.063	15.656	11.674	4.3361	-4.294



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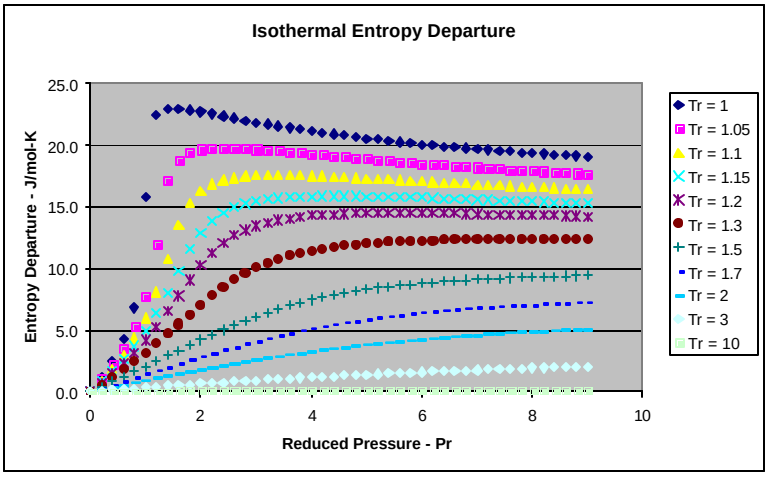
Water

Figure 4 Entropy Departure

Tc 647.4 Kelvins
Pc 22119248 Pascals
Kode 3

	<==========Tr==========										
Pr	1	1.05	1.1	1.15	1.2	1.3	1.5	1.7	2	3	10
0	0.000	2E-08	2E-08	2E-08	2E-08	1E-08	1E-08	9E-09	7E-09	4E-09	8E-10
0.2	1.151	1.006	0.8861	0.7861	0.7016	0.5681	0.3917	0.2842	0.1882	0.0679	0.0034
0.4	2.527	2.1666	1.8813	1.6505	1.4604	1.1672	0.7928	0.5707	0.3755	0.1348	0.0067
0.6	4.274	3.5518	3.0212	2.6119	2.286	1.7997	1.2027	0.8587	0.5616	0.2007	0.01
0.8	6.795	5.2979	4.3618	3.6955	3.19	2.4678	1.6206	1.1478	0.7463	0.2656	0.0133
1	15.775	7.7352	5.9969	4.9345	4.185	3.1723	2.0454	1.437	0.9293	0.3294	0.0165
1.2	22.507	11.989	8.0847	6.3691	5.2823	3.9125	2.4752	1.7255	1.1102	0.3922	0.0198
1.4	22.930	17.136	10.787	8.0267	6.4843	4.6844	2.9082	2.0124	1.2886	0.4539	0.023
1.6	22.965	18.781	13.561	9.8471	7.7684	5.4792	3.3415	2.2966	1.4644	0.5146	0.0261
1.8	22.869	19.404	15.341	11.578	9.0659	6.2818	3.7721	2.577	1.6372	0.5742	0.0293
2	22.723	19.678	16.306	12.935	10.267	7.0707	4.1965	2.8526	1.8066	0.6326	0.0324
2.2	22.555	19.793	16.852	13.879	11.278	7.8211	4.611	3.1223	1.9725	0.69	0.0355
2.4	22.381	19.823	17.176	14.515	12.072	8.51	5.0119	3.3849	2.1345	0.7463	0.0386
2.6	22.207	19.806	17.372	14.948	12.674	9.1222	5.3958	3.6396	2.2924	0.8015	0.0417
2.8	22.038	19.761	17.489	15.248	13.126	9.6521	5.7597	3.8854	2.4461	0.8557	0.0447
3	21.874	19.698	17.555	15.459	13.467	10.102	6.1014	4.1216	2.5953	0.9087	0.0477
3.2	21.716	19.625	17.586	15.607	13.726	10.481	6.4196	4.3476	2.7399	0.9607	0.0507
3.4	21.564	19.546	17.593	15.711	13.923	10.797	6.7136	4.563	2.8798	1.0115	0.0536
3.6	21.420	19.464	17.584	15.782	14.075	11.062	6.9836	4.7675	3.0149	1.0613	0.0566
3.8	21.281	19.38	17.563	15.83	14.191	11.282	7.2302	4.9611	3.1451	1.1101	0.0595
4	21.149	19.296	17.534	15.859	14.28	11.466	7.4559	5.1438	3.2705	1.1578	0.0624
4.2	21.022	19.212	17.498	15.875	14.348	11.621	7.6582	5.3157	3.3911	1.2044	0.0653
4.4	20.901	19.129	17.457	15.881	14.399	11.751	7.8424	5.4771	3.5069	1.25	0.0681
4.6	20.785	19.047	17.414	15.878	14.437	11.86	8.009	5.6284	3.6179	1.2946	0.0709
4.8	20.674	18.967	17.368	15.869	14.465	11.952	8.1595	5.7699	3.7243	1.3382	0.0737
5	20.568	18.889	17.321	15.854	14.483	12.029	8.2954	5.9022	3.8261	1.3808	0.0765
5.2	20.465	18.813	17.273	15.836	14.494	12.094	8.4181	6.0257	3.9235	1.4224	0.0793
5.4	20.367	18.739	17.225	15.814	14.5	12.149	8.529	6.141	4.0165	1.4631	0.082
5.6	20.272	18.666	17.176	15.79	14.5	12.195	8.6292	6.2484	4.1053	1.5028	0.0847
5.8	20.181	18.596	17.128	15.764	14.497	12.234	8.7198	6.3486	4.1901	1.5416	0.0874
6	20.093	18.527	17.079	15.737	14.491	12.266	8.8018	6.4419	4.271	1.5794	0.0901
6.2	20.009	18.461	17.031	15.708	14.481	12.293	8.876	6.5289	4.3482	1.6164	0.0928
6.4	19.927	18.396	16.984	15.679	14.47	12.315	8.9433	6.6099	4.4217	1.6524	0.0954
6.6	19.848	18.333	16.937	15.648	14.456	12.333	9.0043	6.6855	4.4918	1.6876	0.098
6.8	19.772	18.271	16.891	15.618	14.441	12.347	9.0596	6.7559	4.5586	1.722	0.1006
7	19.698	18.211	16.846	15.587	14.425	12.357	9.1099	6.8215	4.6222	1.7555	0.1032
7.2	19.627	18.153	16.801	15.556	14.407	12.366	9.1555	6.8829	4.6828	1.7882	0.1058
7.4	19.558	18.096	16.757	15.525	14.389	12.371	9.1969	6.9399	4.7405	1.8201	0.1083
7.6	19.491	18.041	16.713	15.494	14.37	12.375	9.2345	6.9927	4.7956	1.8512	0.1108
7.8	19.426	17.987	16.671	15.463	14.35	12.377	9.2687	7.0442	4.848	1.8816	0.1133
8	19.363	17.934	16.629	15.432	14.33	12.377	9.2998	7.0684	4.8979	1.9112	0.1158
8.2	19.301	17.883	16.588	15.401	14.309	12.375	9.328	7.1308	4.9455	1.9401	0.1183
8.4	19.242	17.833	16.548	15.371	14.288	12.372	9.3536	7.175	4.9908	1.9683	0.1207
8.6	19.184	17.785	16.509	15.34	14.267	12.369	9.3768	7.2117	5.034	1.9957	0.1231
8.8	19.128	17.737	16.47	15.31	14.246	12.364	9.3979	7.2469	5.0752	2.0225	0.1255
9	19.073	17.691	16.432	15.281	14.225	12.358	9.417	7.2805	5.1144	2.0487	0.1279



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Water

Figure 5 Fugacity Coeffficient

Tc 647.4 Kelvins
Pc 22119248 Pascals
Kode 4

<=========Tr=========>

Pr	1	1.05	1.1	1.15	1.2	1.3	1.5	1.7	2	3	10
0	1.000	1	1	1	1	1	1	1	1	1	1
0.2	0.933	0.9416	0.949	0.9553	0.96073	0.9693	0.98077	0.9877	0.9937	1.0003	1.001
0.4	0.867	0.8844	0.8992	0.9118	0.92244	0.9395	0.96205	0.9757	0.9875	1.0007	1.003
0.6	0.802	0.8283	0.8506	0.8692	0.88509	0.9104	0.94384	0.964	0.9816	1.0012	1.004
0.8	0.736	0.7729	0.8028	0.8277	0.8487	0.8821	0.92616	0.9528	0.9759	1.0017	1.006
1	0.666	0.7174	0.7558	0.7871	0.81327	0.8546	0.90902	0.9418	0.9704	1.0023	1.007
1.2	0.582	0.6603	0.7094	0.7474	0.77885	0.828	0.89244	0.9313	0.9651	1.0029	1.009
1.4	0.519	0.6019	0.6635	0.7089	0.74554	0.8023	0.87644	0.9211	0.96	1.0036	1.01
1.6	0.472	0.5519	0.6195	0.6718	0.71354	0.7777	0.86104	0.9113	0.9552	1.0044	1.012
1.8	0.436	0.5116	0.58	0.6369	0.68316	0.7541	0.84626	0.9019	0.9506	1.0052	1.013
2	0.406	0.4787	0.5463	0.6053	0.65481	0.7318	0.83212	0.8929	0.9462	1.0062	1.015
2.2	0.382	0.4516	0.5176	0.5772	0.62885	0.7108	0.81865	0.8843	0.942	1.0071	1.016
2.4	0.362	0.4291	0.4934	0.5527	0.60544	0.6912	0.80585	0.8761	0.938	1.0082	1.018
2.6	0.346	0.41	0.4726	0.5313	0.58453	0.673	0.79374	0.8683	0.9343	1.0092	1.019
2.8	0.331	0.3937	0.4548	0.5127	0.56596	0.6564	0.78232	0.8609	0.9308	1.0104	1.021
3	0.319	0.3797	0.4394	0.4964	0.54948	0.6412	0.77159	0.8539	0.9275	1.0116	1.022
3.2	0.309	0.3676	0.4259	0.4821	0.53487	0.6273	0.76156	0.8473	0.9244	1.0129	1.024
3.4	0.300	0.3571	0.4142	0.4695	0.52189	0.6148	0.7522	0.8412	0.9216	1.0142	1.025
3.6	0.292	0.3479	0.4039	0.4584	0.51034	0.6034	0.7435	0.8354	0.9189	1.0156	1.027
3.8	0.285	0.3398	0.3948	0.4486	0.50006	0.5932	0.73545	0.83	0.9165	1.0171	1.028
4	0.279	0.3327	0.3868	0.4399	0.4909	0.5839	0.72801	0.8249	0.9143	1.0186	1.03
4.2	0.274	0.3265	0.3797	0.4322	0.48272	0.5755	0.72115	0.8203	0.9123	1.0202	1.031
4.4	0.269	0.3209	0.3734	0.4253	0.47541	0.5679	0.71486	0.816	0.9105	1.0219	1.033
4.6	0.265	0.316	0.3679	0.4191	0.46889	0.5611	0.70911	0.812	0.9089	1.0236	1.035
4.8	0.261	0.3117	0.3629	0.4137	0.46307	0.555	0.70386	0.8084	0.9075	1.0253	1.036
5	0.258	0.3078	0.3585	0.4089	0.45788	0.5495	0.69909	0.8052	0.9063	1.0272	1.038
5.2	0.255	0.3045	0.3547	0.4046	0.45325	0.5446	0.69477	0.8022	0.9052	1.029	1.039
5.4	0.252	0.3015	0.3512	0.4007	0.44915	0.5402	0.69088	0.7995	0.9044	1.031	1.041
5.6	0.250	0.2989	0.3482	0.3974	0.44551	0.5363	0.68739	0.7972	0.9037	1.033	1.042
5.8	0.248	0.2966	0.3456	0.3944	0.44231	0.5328	0.68429	0.7951	0.9033	1.035	1.044
6	0.247	0.2947	0.3433	0.3919	0.4395	0.5297	0.68154	0.7933	0.903	1.0371	1.045
6.2	0.245	0.293	0.3413	0.3896	0.43705	0.5271	0.67914	0.7918	0.9028	1.0393	1.047
6.4	0.244	0.2916	0.3396	0.3877	0.43494	0.5247	0.67706	0.7905	0.9029	1.0415	1.049
6.6	0.243	0.2904	0.3382	0.3861	0.43314	0.5227	0.67528	0.7894	0.9031	1.0438	1.05
6.8	0.243	0.2894	0.3371	0.3847	0.43163	0.5211	0.6738	0.7886	0.9034	1.0461	1.052
7	0.242	0.2886	0.3361	0.3836	0.43039	0.5197	0.67259	0.788	0.9039	1.0485	1.053
7.2	0.242	0.2881	0.3354	0.3827	0.4294	0.5185	0.67164	0.7877	0.9046	1.0509	1.055
7.4	0.241	0.2877	0.3349	0.3821	0.42865	0.5177	0.67094	0.7875	0.9054	1.0534	1.056
7.6	0.241	0.2875	0.3345	0.3816	0.42812	0.5171	0.67047	0.7875	0.9063	1.056	1.058
7.8	0.241	0.2874	0.3344	0.3814	0.42781	0.5167	0.67024	0.7878	0.9074	1.0586	1.06
8	0.241	0.2875	0.3344	0.3813	0.42769	0.5165	0.67022	0.7882	0.9086	1.0612	1.061
8.2	0.242	0.2877	0.3346	0.3815	0.42776	0.5165	0.6704	0.7888	0.91	1.0639	1.063
8.4	0.242	0.2881	0.3349	0.3817	0.42801	0.5167	0.67079	0.7896	0.9115	1.0667	1.064
8.6	0.243	0.2886	0.3353	0.3822	0.42843	0.5171	0.67137	0.7905	0.9131	1.0695	1.066
8.8	0.243	0.2892	0.336	0.3828	0.42902	0.5177	0.67213	0.7917	0.9149	1.0724	1.068
9	0.244	0.2899	0.3367	0.3835	0.42976	0.5185	0.67307	0.7929	0.9168	1.0753	1.069

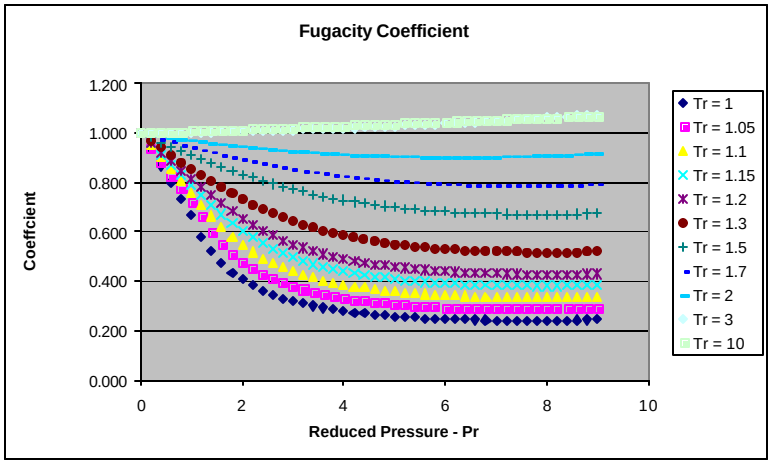

Figure 6 Comparing Rkfunc to Charts

Tc	647.4	Kelvins
Pc	22119247.5	Pascals

	Tr	Pr	Kode	Values
Compressibility	1.4	1.51	1	0.824636
Enthalpy Departure	1.23	1.37	2	9.648814
Entropy Departure	1.23	1.37	3	5.661568
Fugacity	1.7	1.49	4	0.916666