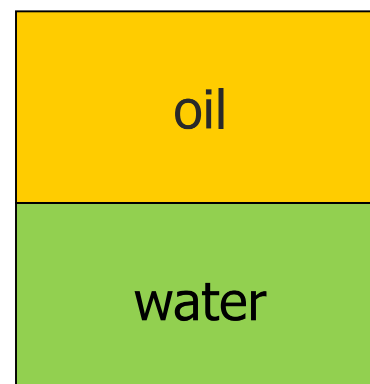
Pure Substance

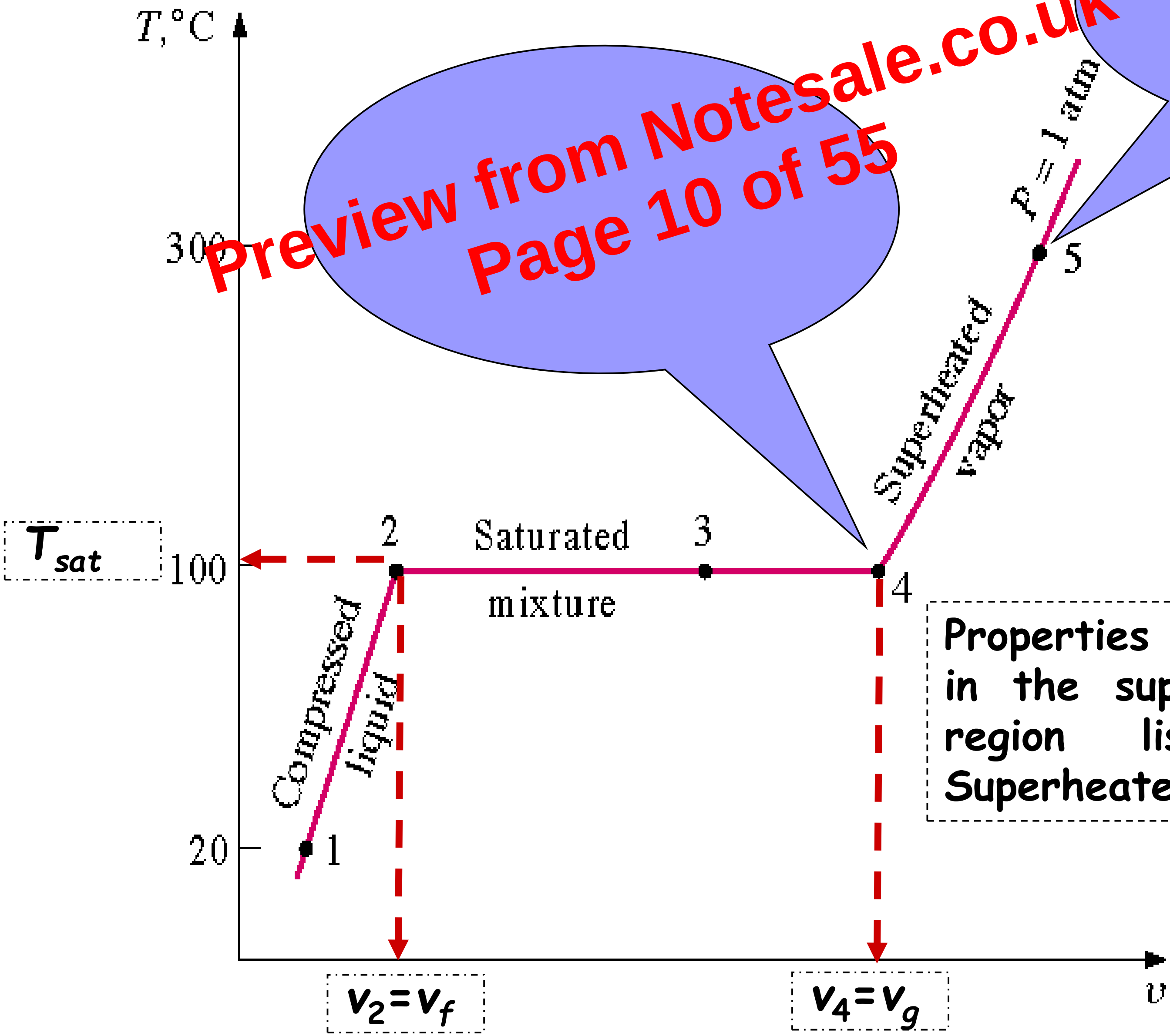
- A substance that has a fixed chemical composition throughout is called a pure substance, e.g.: H_2O, N_2, CO_2
- A pure substance does not have to be of a single chemical element or compound
- A mixture of chemical elements/compounds also qualifies as a pure substance as long as the mixture is homogeneous, e.g. Air
- However, a mixture of oil and water is not a pure substance - oil is not homogeneous/soluble in water, forming two chemically dissimilar regions



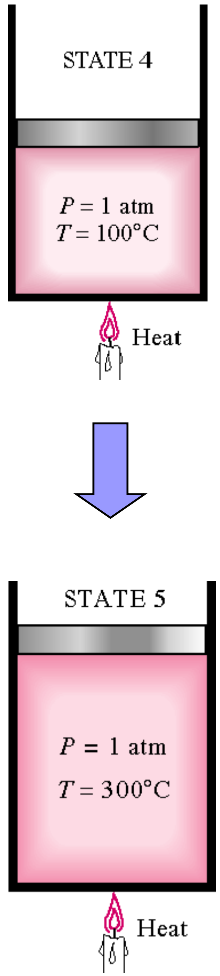
Phases Of Pure Substances

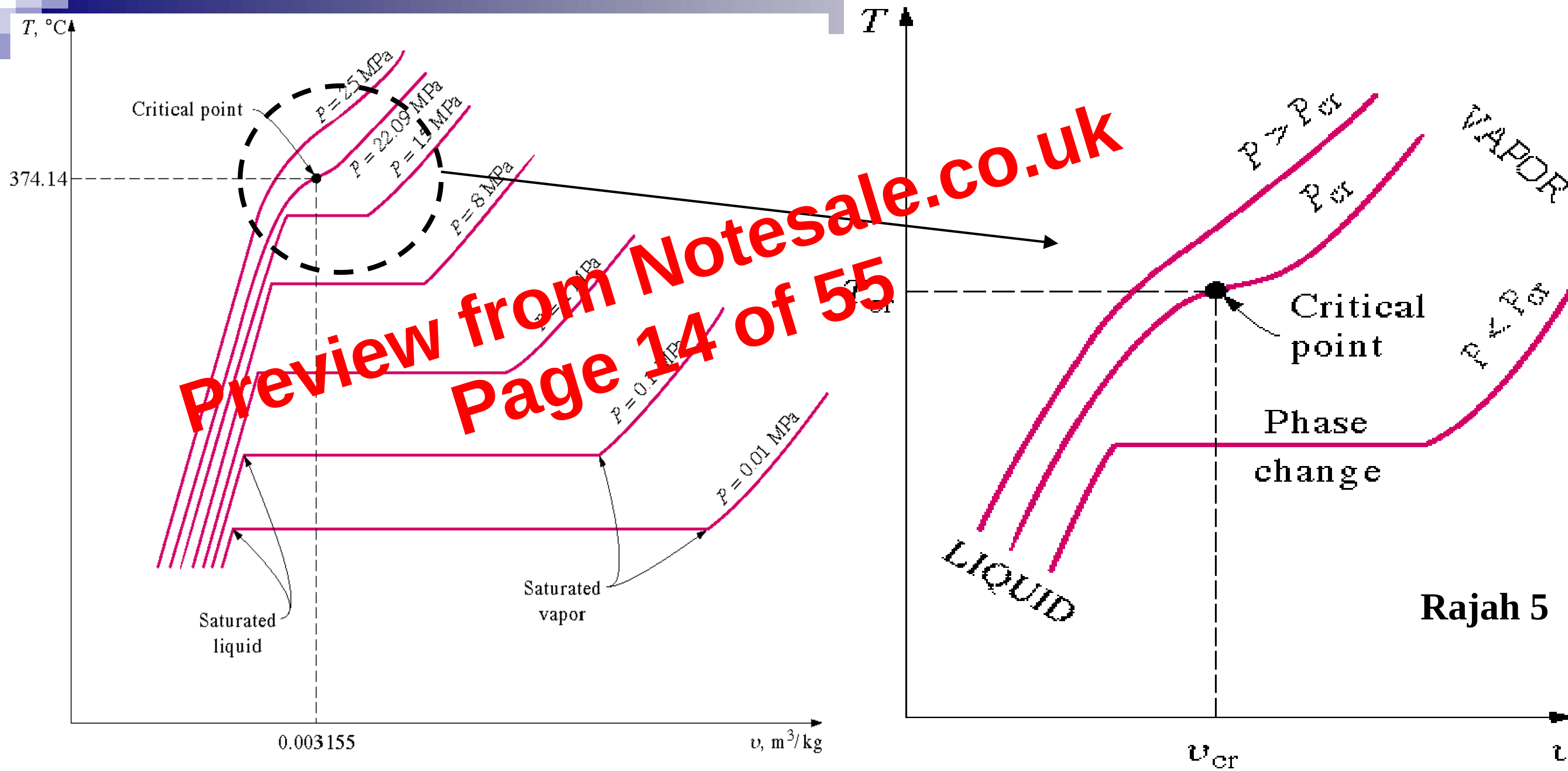
- A phase is identified as having a distinct molecular arrangement that is homogeneous throughout and separated from the others by easily identifiable boundary surfaces. Eg: Two phases of water in iced water
- Three principal phases: solid, liquid and gas
- A substance may have several phases within a principal phase, each with a different molecular structure. For eg:
  - Helium has two liquid phases;
  - Iron has three solid phases.

PROCESS 4-5



Properties of water in the superheated region listed in Superheated Tables





Rajah 5

- Above critical temperature and pressure ➔ <u>no significant process of phase change occurs</u>.
- The volume continues to increase and only one phase that similar to vapour phase exists.

Quality and saturated region

- During vaporization, a substance exists in two phases (liquid and vapour) that consists of a mixture of saturated liquid and saturated vapour. The ratio of vapor to the total mass of mixture is quality.

$$x = \frac{m_{\text{vapour}}}{m_{\text{total}}} = \frac{m_{\text{vapour}}}{m_{\text{liquid}} + m_{\text{vapour}}} = \frac{m_g}{m_f + m_g}$$

- x=0 (or 0%) for saturated liquid and x=1 (or 100%) for saturated vapour, so the range for quality is $0 \le x \le 1$.
- Quality has significance for saturated mixtures only. It has no meaning in the compressed liquid or superheated vapor regions.
- The properties of the saturated liquid are the same whether it exists alone or in a mixture with saturated vapor. During the vaporization process, only the amount of saturated liquid changes, not its properties. Similarly to a saturated vapor.

Example of compressed liquid table

The format of Table 1–7 is similar to the superheated vapor tables, except the saturated data represent the saturated liquid properties

T_{sat}

TABLE A–7

Compressed liquid water

T °C	v m³/kg	u kJ/kg	h kJ/kg	s kJ/kg · K	v m³/kg	u kJ/kg	h kJ/kg	s kJ/kg · K	v m³/kg	u kJ/kg	h kJ/kg	s kJ/kg · K
	P = 5 MPa (263.94°C)				P = 10 MPa (311.00°C)				P = 15 MPa (342.16°C)			
Sat.	0.0012862	[illegible]	[illegible]	2.9207	[illegible]	1393.3	1407.9	3.3603	0.0016572	1585.5	1610.3	3.6848
0	[illegible]	[illegible]	5.03	0.0001	[illegible]	0.12	10.07	0.0003	0.0009928	0.18	15.07	0.0004
20	[illegible]	83.61	[illegible]	[illegible]	0.0009973	83.31	93.28	0.2943	0.0009951	83.01	97.93	[illegible]
40	0.0010057	166.92	[illegible]	0.5705	0.0010035	166.33	176.37	0.5685	0.0010013	165.75	180.77	0.5666
60	0.0010149	[illegible]	[illegible]	0.8287	0.0010127	249.43	259.55	0.8260	0.0010105	248.58	263.74	0.8234
80	[illegible]	[illegible]	338.96	1.0723	0.0010244	332.69	342.94	1.0691	0.0010221	331.59	346.92	1.0659
100	[illegible]	[illegible]	422.85	1.3034	0.0010385	416.23	426.62	1.2996	0.0010361	414.85	430.39	1.2958
120	0.0010576	501.91	507.19	1.5236	0.0010549	500.18	510.73	1.5191	0.0010522	498.50	514.28	1.5148
140	0.0010769	586.80	592.18	1.7344	0.0010738	584.72	595.45	1.7293	0.0010708	582.69	598.75	1.7243
160	0.0010988	672.55	678.04	1.9374	0.0010954	670.06	681.01	1.9316	0.0010920	667.63	684.01	1.9259
180	0.0011240	759.47	765.09	2.1338	0.0011200	756.48	767.68	2.1271	0.0011160	753.58	770.32	2.1206
200	0.0011531	847.92	853.68	2.3251	0.0011482	844.32	855.80	2.3174	0.0011435	840.84	858.00	2.3100
220	0.0011868	938.39	944.32	2.5127	0.0011809	934.01	945.82	2.5037	0.0011752	929.81	947.43	2.4951
240	0.0012268	1031.6	1037.7	2.6983	0.0012192	1026.2	1038.3	2.6876	0.0012121	1021.0	1039.2	2.6774
260	0.0012755	1128.5	1134.9	2.8841	0.0012653	1121.6	1134.3	2.8710	0.0012560	1115.1	1134.0	2.8586
280					0.0013226	1221.8	1235.0	3.0565	0.0013096	1213.4	1233.0	3.0410
300					0.0013980	1329.4	1343.3	3.2488	0.0013783	1317.6	1338.3	3.2279
320									0.0014733	1431.9	1454.0	3.4263
340									0.0016311	1567.9	1592.4	3.6555

T °C	v m³/kg	u kJ/kg	h kJ/kg	s kJ/kg · K	v m³/kg	u kJ/kg	h kJ/kg	s kJ/kg · K	v m³/kg	u kJ/kg	h kJ/kg	s kJ/kg · K
	P = 20 MPa (365.75°C)				P = 30 MPa				P = 50 MPa			
Sat.	0.0020378	1785.8	1826.6	4.0146								
0	0.0009904	0.23	20.03	0.0005	0.0009857	0.29	29.86	0.0003	0.0009767	0.29	49.13	−0.0010
20	0.0009929	82.71	102.57	0.2921	0.0009886	82.11	111.77	0.2897	0.0009805	80.93	129.95	0.2845
40	0.0009992	165.17	185.16	0.5646	0.0009951	164.05	193.90	0.5607	0.0009872	161.90	211.25	0.5528
60	0.0010084	247.75	267.92	0.8208	0.0010042	246.14	276.26	0.8156	0.0009962	243.08	292.88	0.8055
80	0.0010199	330.50	350.90	1.0627	0.0010155	328.40	358.86	1.0564	0.0010072	324.42	374.78	1.0442
100	0.0010337	413.50	434.17	1.2920	0.0010290	410.87	441.74	1.2847	0.0010201	405.94	456.94	1.2705
120	0.0010496	496.85	517.84	1.5105	0.0010445	493.66	525.00	1.5020	0.0010349	487.69	539.43	1.4859
140	0.0010679	580.71	602.07	1.7194	0.0010623	576.90	608.76	1.7098	0.0010517	569.77	622.36	1.6916
160	0.0010886	665.28	687.05	1.9203	0.0010823	660.74	693.21	1.9094	0.0010704	652.33	705.85	1.8889
180	0.0011122	750.78	773.02	2.1143	0.0011049	745.40	778.55	2.1020	0.0010914	735.49	790.06	2.0790
200	0.0011390	837.49	860.27	2.3027	0.0011304	831.11	865.02	2.2888	0.0011149	819.45	875.19	2.2628
220	0.0011697	925.77	949.16	2.4867	0.0011595	918.15	952.93	2.4707	0.0011412	904.39	961.45	2.4414
240	0.0012053	1016.1	1040.2	2.6676	0.0011927	1006.9	1042.7	2.6491	0.0011708	990.55	1049.1	2.6156
260	0.0012472	1109.0	1134.0	2.8469	0.0012314	1097.8	1134.7	2.8250	0.0012044	1078.2	1138.4	2.7864
280	0.0012978	1205.6	1231.5	3.0265	0.0012770	1191.5	1229.8	3.0001	0.0012430	1167.7	1229.9	2.9547
300	0.0013611	1307.2	1334.4	3.2091	0.0013322	1288.9	1328.9	3.1761	0.0012879	1259.6	1324.0	3.1218
320	0.0014450	1416.6	1445.5	3.3996	0.0014014	1391.7	1433.7	3.3558	0.0013409	1354.3	1421.4	3.2888
340	0.0015693	1540.2	1571.6	3.6086	0.0014932	1502.4	1547.1	3.5438	0.0014049	1452.9	1523.1	3.4575
360	0.0018248	1703.6	1740.1	3.8787	0.0016276	1626.8	1675.6	3.7499	0.0014848	1556.5	1630.7	3.6301
380					0.0018729	1782.0	1838.2	4.0026	0.0015884	1667.1	1746.5	3.8102

Example 2.1

Using Property Tables, complete this table for H_2O:

	P (MPa)	v (m^3/kg)	T (°C)	Phase and Quality
(a)		1.725	100	
(b)	0.85	0.227		
(c)	15		400	
(d)		0.001124	180	
(e)	0.75	0.221		
(f)		0.3879	150	
(g)	0.25	0.095		

The Compressibility Factor, Z

- From the Generalized Compressibility Chart, the following observation can be made :

  1.) At **very low** pressures ($P_R << 1$), gases behave as an Ideal Gas regardless of Temperature.

  2.) At **high** temperatures ($T_R > 2$), Ideal Gas behaviour can be assumed with good accuracy regardless of Pressure except when $P_R >> 1$.

  3.) The deviation of a gas from Ideal Gas behaviour is **greatest** in the vicinity of the Critical Point.

INTERNAL ENERGY, ENTHALPY AND SPECIFIC HEATS OF SOLIDS AND LIQUIDS

- A substance whose specific volume (or density) is constant ➔ incompressible substance - the specific volumes of solids and liquids essentially remain constant during a process.
- The constant-volume and constant-pressure specific heats are identical for incompressible substances:

$$\boxed{C_V = C_P = C \qquad (\text{kJ/kg.K})}$$

- Specific heat values for several common liquids and solids are given in Table A–3.
- The specific heats of incompressible substances depend on *T* only. Thus, internal energy of the incompressible substances:

$$\boxed{du = CdT \xrightarrow{\text{integration}} \Delta u = C_{ave}(T_2 - T_1)}$$

Enthalpy?? ???