**Chemical Engineering 141 2nd Midterm**

H = U + PV

A = U – TS

G = H – TS

dU = TdS – PdV

dH = TdS + VdP

dA = -PdV – SdT

dG = VdP – SdT

Enthalpy as a function of T and P

Entropy as a function of T and P

Internal Energy as a function of P

Idealgas

Alternative forms for liquids

**Internal Energy as function of T and V**

**The Gibbs Energy as a Generating Function**

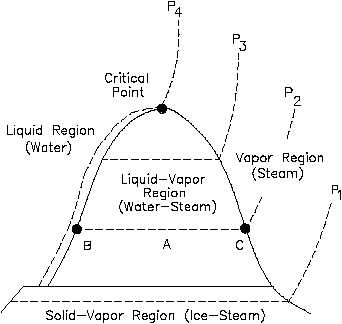
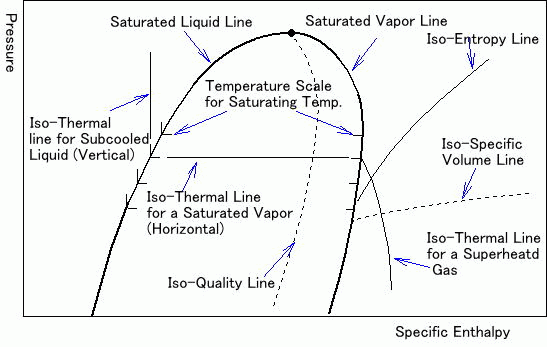
**Residual properties**

MR = M-Mig

|  |  |  |
| --- | --- | --- |
|  | Virial EOS | Cubic EOS |
|  |  |  |
|  |  |  |
|  |  |  |

**Two Phase Systems**

Liquid/Vapor Systems



**Generalized property correlations for gases**

**Equations of Balance**

|  |  |  |
| --- | --- | --- |
| General equations | Steady-flow | Single-stream steady-flow |
|  |  |  |
|  |  |  |
|  |  |  |

**Throttling process**

**Joule/Thomson coefficient**

**Turbines (expanders)**

**Compression processes**

**Pumps**

**Rankine Cycle**

|  |  |
| --- | --- |
| File:Rankine cycle Ts.png | 1-2: reversible, adiabatic (isentropic) pumping of the saturated liquid to the pressure of the boiler, producing compressed (subcooled) liquid.  2-3: heating of subcooled liquid water to its saturation temperature, vaporization at constant temperature and pressure, and superheating of the vapor to a temperature well above its saturation temperature  3-4: reversible, adiabatic (isentropic) expansion of vapor in a turbine to the pressure of the condenser.  4-1: constant-pressure, constant temperature process in a condenser to product saturated liquid |

 \eta_{therm}=\frac{\dot{W}_{turbine}-\dot{W}_{pump}}{\dot{Q}_{in}} \approx \frac{\dot{W}_{turbine}}{\dot{Q}_{in}}.

\frac{\dot{Q}_{in}}{\dot{m}}=h_3-h_2 \frac{\dot{Q}_{out}}{\dot{m}}=h_4-h_1 \frac{\dot{W}_{pump}}{\dot{m}}=h_2-h_1 \frac{\dot{W}_{turbine}}{\dot{m}}=h_3-h_4

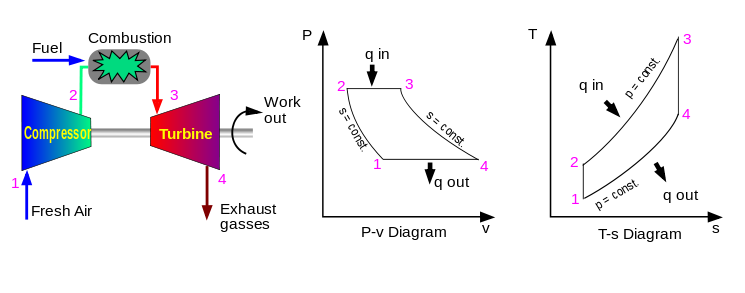
Otto cycle

|  |  |
| --- | --- |
| http://upload.wikimedia.org/wikipedia/commons/thumb/c/cf/P-V_otto.png/300px-P-V_otto.pnghttp://upload.wikimedia.org/wikipedia/commons/thumb/6/6d/Otto2.png/300px-Otto2.png | * 1. intake stroke   A mass of air (working fluid) is drawn into the cylinder, from 0 to 1, at atmospheric pressure (constant pressure) through the open intake valve  1-2 compression stroke  Isentropic compression, compression ratio V1/V2  2-3 ignition  Isochoric, heat is added, pressure rises, temperature increases, pressure ratio P3/P2  3-4 expansion stroke  Fluid expands isentropically, expansion ratio, V4/V3  4-1 heat ejection  Isochoric, heat is removed, pressure drops, temperature decreases |

Diesel cycle

|  |  |
| --- | --- |
| File:DieselCycle PV.svg | 1-2 isentropic compression  2-3 isobaric expansion  3-4 isentropic expansion  4-1 isochoric cooling |

Brayton Cycle / Gas Turbine Engine



1-2 isentropic compression

2-3 isobaric expansion/heating

3-4 isentropic expansion/cooling

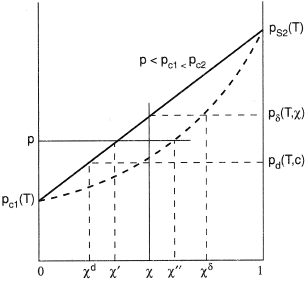
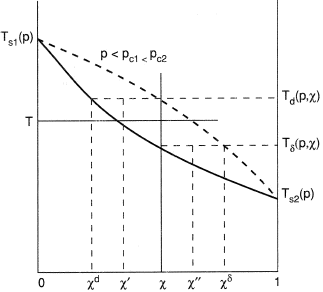
4-1 isobaric compression

**Refrigeration**

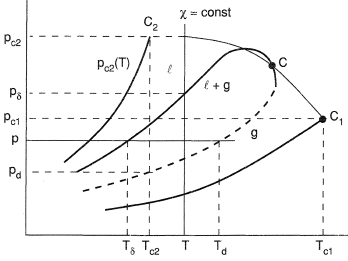
|  |  |  |
| --- | --- | --- |
| http://www.qrg.northwestern.edu/thermo/design-library/refrig/Ts.gif | | simple refrigeration cycle |
|  | |  |
| **Claude liquefaction process** | [http://lh4.ggpht.com/_YOjepBEvjc8/TF7iAo6HfVI/AAAAAAAAD9I/tyNbNHVQWGk/s400/Linde_simple_process.GIF](http://lh4.ggpht.com/_YOjepBEvjc8/TF7iAo6HfVI/AAAAAAAAD9I/tyNbNHVQWGk/s800/Linde_simple_process.GIF)  **Linde liquefaction process** | |

|  |  |
| --- | --- |
|  |  |

**Phase Rule**:

P-x diagram T-x digram

 PT diagram

|  |  |
| --- | --- |
| http://readysleep.files.wordpress.com/2008/04/henrys-law.png | |
| Modified Raoult’s law  y is vapor phase  x is liquid phase |  |

Antoine equation

|  |  |
| --- | --- |
| **Bubble point {xi}, T, given**   1. get {Pisat} by T | **Dew point {yi}, T, given**   1. get {Pisat} by T |
| **Bubble point {xi}, P, given**   1. Plug P into Antoine equation as the Pisat to calculate Tisat. As an initial guess 2. Calculate {Pisat} at this T. 3. Choose one species k as a reference:      1. Plug in P1sat or P2sat in Antoine equation to get a new value for T. 2. Go back to step 2 until T converges. | **Dew point {yi}, P, given**   1. Plug P into Antoine equation as the Pisat to calculate Tisat. As an initial guess 2. Calculate {Pisat} at this T. 3. Choose one species k as a reference:   ) )   1. Plug in P1sat or P2sat in Antoine equation to get a new value for T. 2. Go back to step 2 until T converges. |