CH365 Chemical Engineering Thermodynamics

Lesson 17

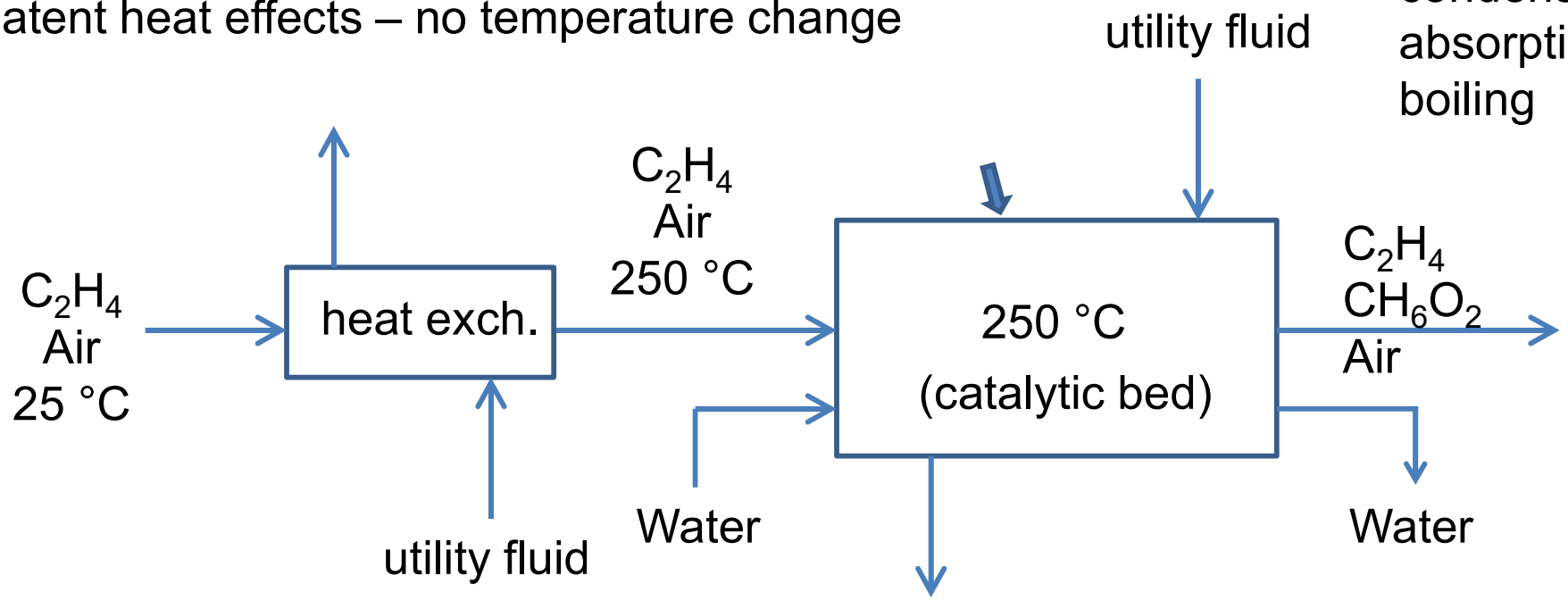
Latent Heat and Heats of Reaction, Formation, and Combustion

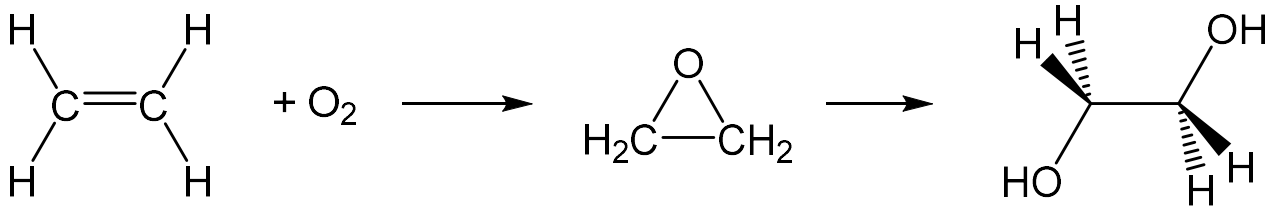
Ethylene Glycol Process

Sensible heat effects – temperature change

➡ Latent heat effects – no temperature change

distillation
condensation
absorption
boiling





ethylene

ethylene oxide

ethylene glycol

Latent Heats of Pure Substances

One component evaporating or condensing – No temperature change but heat is transferred. Latent heat of fusion / vaporization.

Latent Heats of Pure Substances

One component evaporating or condensing.

Latent Heats of Pure Substances

One component evaporating or condensing.

Standard Heat of Reaction

Heat effects in chemical reactions are manifestations of the differences in molecular structure.

There are a large number of chemical reactions, each of which can be carried out at an essentially infinite set of process conditions.

Tabulation of all possible heat effects for all possible reactions is *impossible*.

Heats are calculated from data for reactions conducted under standard conditions.

Heat associated with a chemical reaction depends on the temperatures of the reactants and products. A consistent standard treatment is that products and reactants at same temperature.

Standard Heat of Reaction

Tabulation of all possible heat effects for all possible reactions is impossible. Heats are calculated from data for reactions conducted under standard conditions.

Products and reactants are at the same temperature

$$aA + bB \rightarrow pP + rR$$

Standard Heat of Reaction is the enthalpy change when *a* moles of *A* and *b* moles of *B* in their standard states at temperature T react to form *p* moles of *P* and *r* moles of *R* in their standard states at temperature T

Standard States:

Gases: ideal gas at 1 bar

Liquids and Solids: real pure liquid or solid at 1 bar

Table C.4, page 672

$\frac{1}{2}N_2 + \frac{3}{2}H_2 \rightarrow NH_3 \qquad \Delta H^{o}_{298} = -46,110\,J$

$N_2 + 3H_2 \rightarrow 2NH_3 \qquad \Delta H^{o}_{298} = -92,220\,J$

Degree symbol designates standard state

$C^{o}_{P} = C^{ig}_{P}$ for gases

ΔH^{o}_{298} Standard value at 298.15 K

Standard state properties are functions of T

Standard Heat of Formation

Tabulation of all possible heats of reaction is not practical. The standard heat of reaction can be calculated if the heats of formation of the reactants and products are known.

In a *formation reaction*, a compound forms from its constituent elements.

$$C(s) + O_2(g) + 2H_2(g) \rightarrow CH_3OH(g)$$

Heat of formation is based on one mole of product

Water-gas-shift reaction:

Table C.4, page 672

$$CO_2(g) \rightarrow C(s) + O_2(g) \qquad \Delta H^o_{298} = 393,509\,J$$

negative in Table C.4 (listed as product)

$$C(s) + \tfrac{1}{2}O_2(g) \rightarrow CO(g) \qquad \Delta H^o_{298} = -110,525\,J$$

$$H_2(g) + \tfrac{1}{2}O_2(g) \rightarrow H_2O(g) \qquad \Delta H^o_{298} = -241,818\,J$$

$$CO_2(g) + H_2(g) \rightarrow CO(g) + H_2O(g) \qquad \Delta H^o_{298} = 41,166\,J$$

Questions?

Homework

Problem 4.10

(a) For one of the compounds listed in Table B.2 of App. B, evaluate the latent heat of vaporization ΔH_n by Eq. 4.13. How does this result compare with the value listed in Table B.2?

(b) Handbook values for latent heats of vaporization at 25 deg C of four compounds are given in the table below. Calculate ΔH_n by Eq. 4.14 and compare the result with the value given in Table B.2. (Problem is continued on page 169.)

Latent heats of vaporization at 25 deg C in J/g			
n-Pentane	366.3	Benzene	433.3
n-Hexane	366.1	Cyclohexane	392.5

Problem 4.12

Handbook values for the latent heat of vaporization in J/g are given in the table (below) for several pure liquids at 0 deg C.

	ΔH^{lv} in J/g at 0 deg
Chloroform	270.9
Methanol	1189.5
Tetrachloromethane	217.8

Calculate:

(a) The value of the latent heat at T_n by Eq. 4.14, given the value at 0 deg C.
(b) The value of the latent heat T_n by Eq. 4.13.

By what percentage do these results differ from the value listed in Table B.2 of App. B?

Problem 4.20

Hydrocarbon fuels can be produced from methanol by reactions such as the following, which yields 1-hexene:

$$6\ CH_3OH(g) \rightarrow \overset{\text{1-hexene}}{C_6H_{12}(g)} + 6\ H_2O(g)$$

Compare the standard heat of combustion at 25 deg C of 6 $CH_3OH(g)$ with the standard heat of combustion at 25 deg C of $C_6H_{12}(g)$ for reaction products $CO_2(g)$ and $H_2O(g)$.

PS6 – Bonus Op – 5 Points

(1) Repeat problem 4.20 with CHEMCAD's standard heats of formation. (2) Use the isothermal Gibbs reactor in CHEMCAD to calculate the "overall heat of reaction." (3) Use the isothermal Gibbs reactor in CHEMCAD to calculate the "heat duty" and explain the difference between the heat duty and the overall heat of reaction.

Complete the following table:

Standard heats of combustion at 25°C (1 and 2) and heat duty (3).

	(1)	(2)	(3)
Methanol			
1-Hexene			