Lecture Notes B: Thermodynamics I (cont)

1) C_V versus C_P

Heat transferred if volume is held constant

$$q_V = n\, C_v\, (T_{final}-T_{initial}) = n\, C_V\ \Delta T$$

Heat transferred if pressure is held constant

$$q_P = n\, C_P\, (T_{final}-T_{initial}) = n\, C_P\ \Delta T$$

n = number of moles of the substance being heated
C = molar heat capacity

2) Heat transfer at constant volume: Bomb Calorimeter

If you seal some chemical species in a constant volume "bomb", and measure the heat produced or consumed in a chemical process, you have measured ΔE.

3) Heat transfer at constant pressure: Definition of enthalpy

If you measure the heat produced or consumed in a chemical process at constant pressure, you have measured ΔH, where H is the enthalpy.

4) Relation to C_p and C_v

5) Energy and heat capacities of an ideal gas

$E = 3/2\ n\ R\ T$ (for a monatomic ideal gas, Ar, Ne, etc., see Section 4.5 between eqs. [4.10] and [4.11])

C_v

C_P

C_v As you heat, all energy goes to the internal motion of molecules,thereby increasing T

C_p As you heat, the volume increases (gas is doing work). So your heat is being used both to increase T and to do work.

6) State functions (Why have this Enthalpy thing?)

A state function is uniquely determined by the thermodynamic state of a system (P,V,T).

Your altitude above sea level is a state function: it does not matter how you got to Pittsburgh.
The amount of gas in your car is not a state function: it depends on how you got here.

$$\Delta E = q + w$$

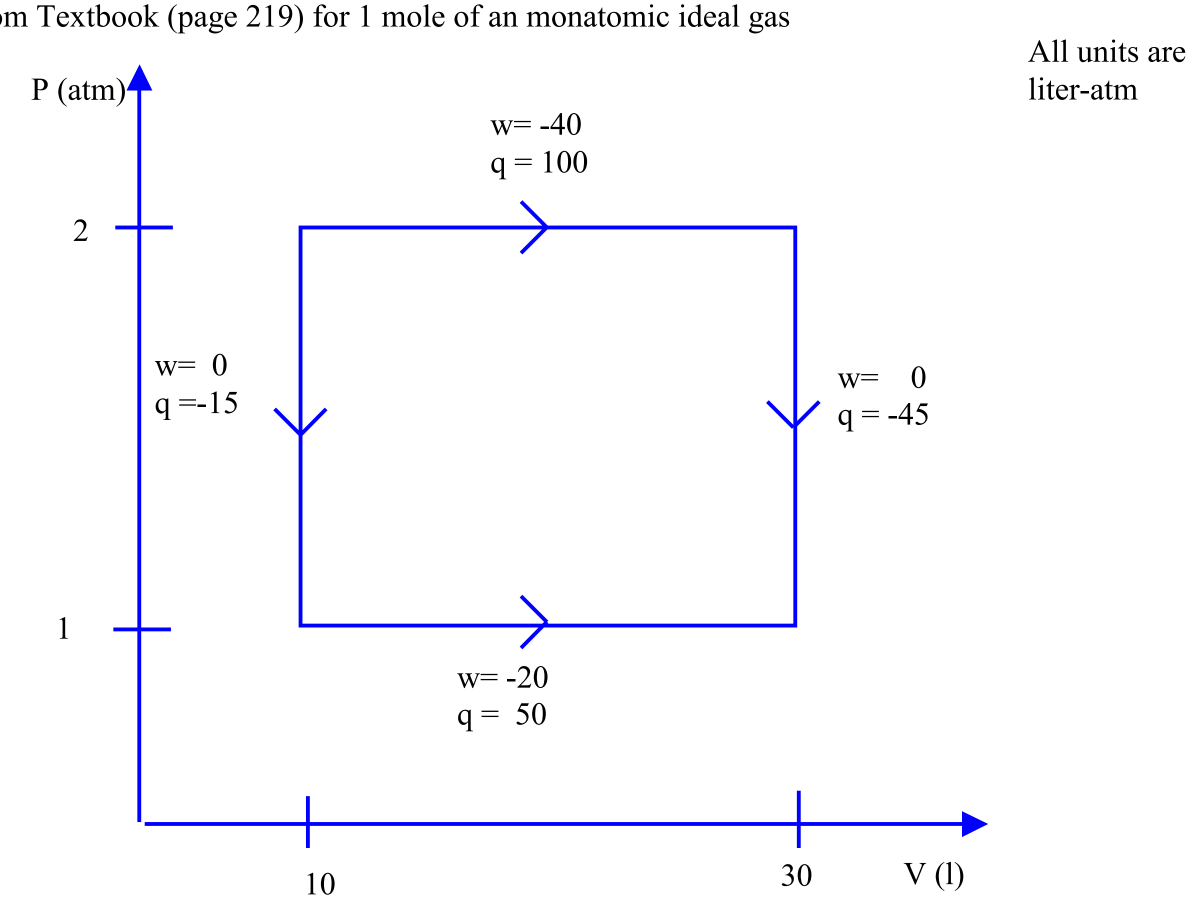
E and H are state functions, q and w are not.

You can't say something "has" a certain amount of heat, but you can say it has a certain amount of energy or enthalpy.

You can extract the energy or enthalpy as either heat or work.

Enthalpy is a great concept, because you typically work at constant pressure. If no work is done, the change in enthalpy is the change in heat for a constant pressure process. This is why the "change in enthalpy" for a chemical reaction is often called the "heat of reaction" (see section 7 of these notes).

From Textbook (page 219) for 1 mole of an monatomic ideal gas



7) Enthalpy of reaction (also called heat of reaction)

Consider burning acetylene: $C_2H_2(g) + 3/2\ O_2(g) \rightarrow CO_2(g) + H_2O(l) \quad \Delta H = -1301.1$ kJ

exothermic:	reactants	$\rightarrow$ products + heat	ΔH negative
endothermic:	reactants + heat	$\rightarrow$ products	ΔH positive

Problem: Calculate the change in enthalpy when 5.00 grams of acetylene is burned.

Concept

What is ΔH for the reaction: $2CO_2(g) + 2H_2O(l) \rightarrow 2C_2H_2(g) + 3\ O_2(g)$

(a) $\Delta H = -2602.2$ kJ (b) $\Delta H = -1301.1$ kJ (c) $\Delta H = 1301.1$ kJ (d) $\Delta H = 2602.2$ kJ

8) Hess's law

$$A + B \rightarrow C \qquad \Delta H_1$$
$$C \rightarrow D + E \qquad \Delta H_2$$
$$A + B \rightarrow D + E \qquad \Delta H = \Delta H_1 + \Delta H_2$$

Problem

Two gaseous pollutants that form in auto exhaust are CO and NO. An elegant way to eliminate these is through the reaction:

$$CO_{(g)} + NO_{(g)} \rightarrow CO_{2\,(g)} + 1/2\ N_{2\,(g)}$$

Calculate ΔH and ΔE for the above reaction given the following (all values are for 25°C),

$$CO_{(g)} + 1/2\ O_{2(g)} \rightarrow CO_{2\,(g)} \qquad \Delta H = -283.0\ kJ$$

$$N_{2\,(g)} + O_{2(g)} \rightarrow 2\ NO_{(g)} \qquad \Delta H = 180.6\ kJ$$

9) Phase changes

$H_2O_{(s)} \rightarrow H_2O_{(l)}$ $|\Delta H_{fus}| = 6.007$ kJ

$H_2O_{(l)} \rightarrow H_2O_{(g)}$ $|\Delta H_{vap}| = 40.7$ kJ

Concept

What are the correct signs for enthalpy's of the above reactions?

a) $\Delta H_{fus} = 6.007$ kJ , $\Delta H_{vap} = 40.7$ kJ
b) $\Delta H_{fus} = 6.007$ kJ , $\Delta H_{vap} = -40.7$ kJ
c) $\Delta H_{fus} = -6.007$ kJ , $\Delta H_{vap} = 40.7$ kJ
d) $\Delta H_{fus} = -6.007$ kJ , $\Delta H_{vap} = -40.7$ kJ

Problem

How many grams of ice (at 0^oC) is needed to cool 1 liter of water from 25^oC to 0^oC?