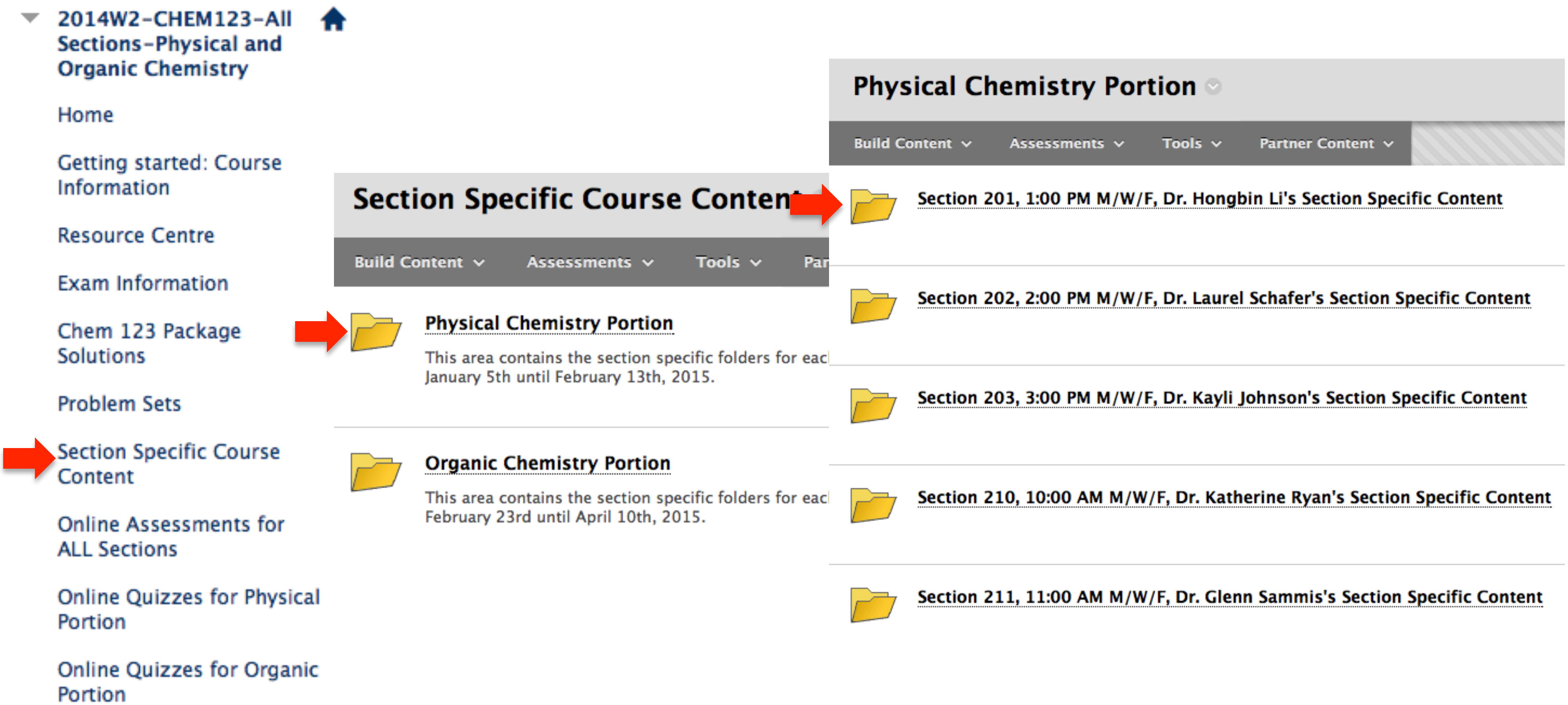
Chem 123 (section 201)
Lecture 3 (Jan. 9)

Announcement and reminder

- Clicker Quiz #1 is available and due Monday Jan. 12!
Input of your answers will be done in class and requires the use of clicker

- My office hours will be Mondays 2-3pm in A247

Clicker Quiz#1 is posted on Chem123 All Section Connect site



The First Law of Thermodynamics:

Conservation of Energy: Energy can neither be created nor destroyed, although it can be converted from one form to another.

There exists a state variable called **internal energy** ***E***. *E* is the sum of all forms of energy in the system. For a closed system:

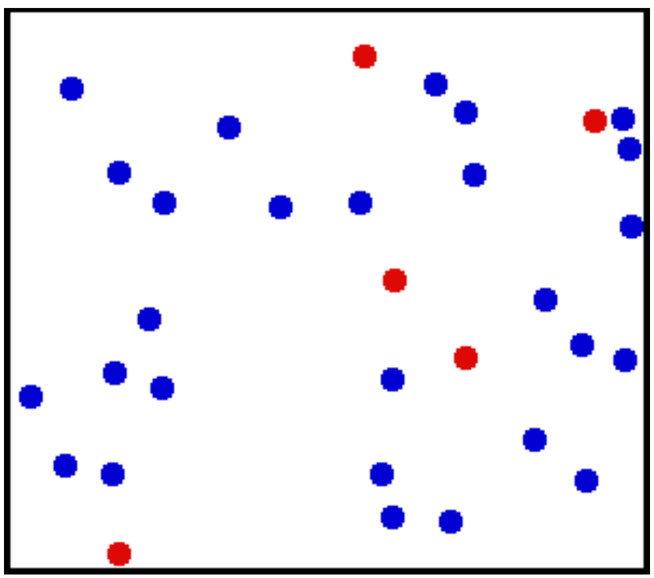
$$\Delta E = q + w$$

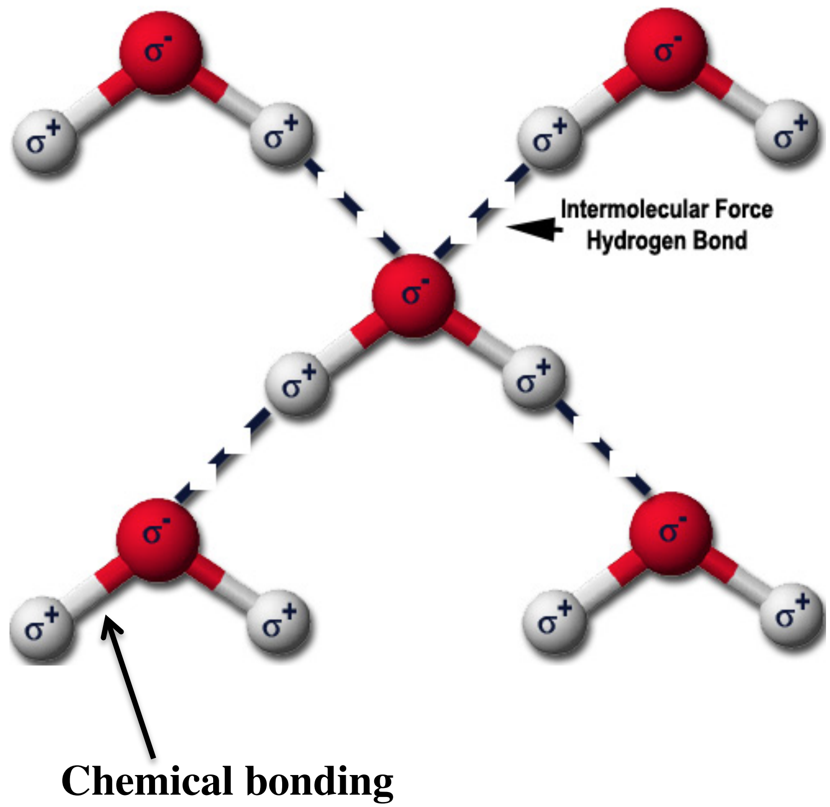
(for all paths)

Internal Energy: E [J], **an extensive property**

Internal energy is comprised of:

- Kinetic energy of molecules (thermal motion)
- Potential energy (intramolecular and intermolecular)





Energy can be exchanged between a closed system and its surroundings in the following ways:

1. Transfer of **Heat (*q*)**
2. Exchange of **Work (*w*)**

Heat *q*:

q is the amount of heat transferred between the system and the surroundings. $[q] = [J]$ (Joules)

$q > 0$: If heat is added to the system from the surroundings
$q < 0$: If the system releases heat to the surroundings

Work w:

w is the amount work transferred between the system and the surroundings. $[w] = [J]$ (Joules) (dw stands for an infinitesimal amount of work transferred)

$w > 0$: If the surroundings do work on the system
$w < 0$: If the system does work on the surroundings

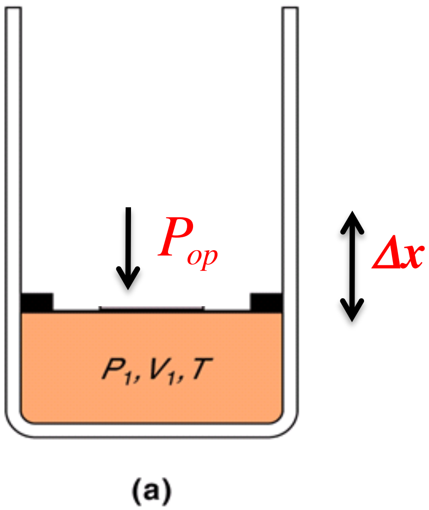
Type of work

TABLE 6.1 Varieties of Work

Type of work	w	Comment
expansion	$-P_{ex}\Delta V$	P_{ex} is the external pressure ΔV is the change in volume
extension	$f\Delta l$	f is the tension Δl is the change in length
weight lifting	$mg\Delta h$	m is the mass g is the acceleration of free fall Δh is the change in height
electrical	$\phi\Delta q$	ϕ is the electrical potential Δq is the change in charge
surface expansion	$\gamma\Delta A$	γ is the surface tension ΔA is the change in area

* For work in joules (J). Note that 1 N·m = 1 J and 1 V·C = 1 J.

Expansion Work:

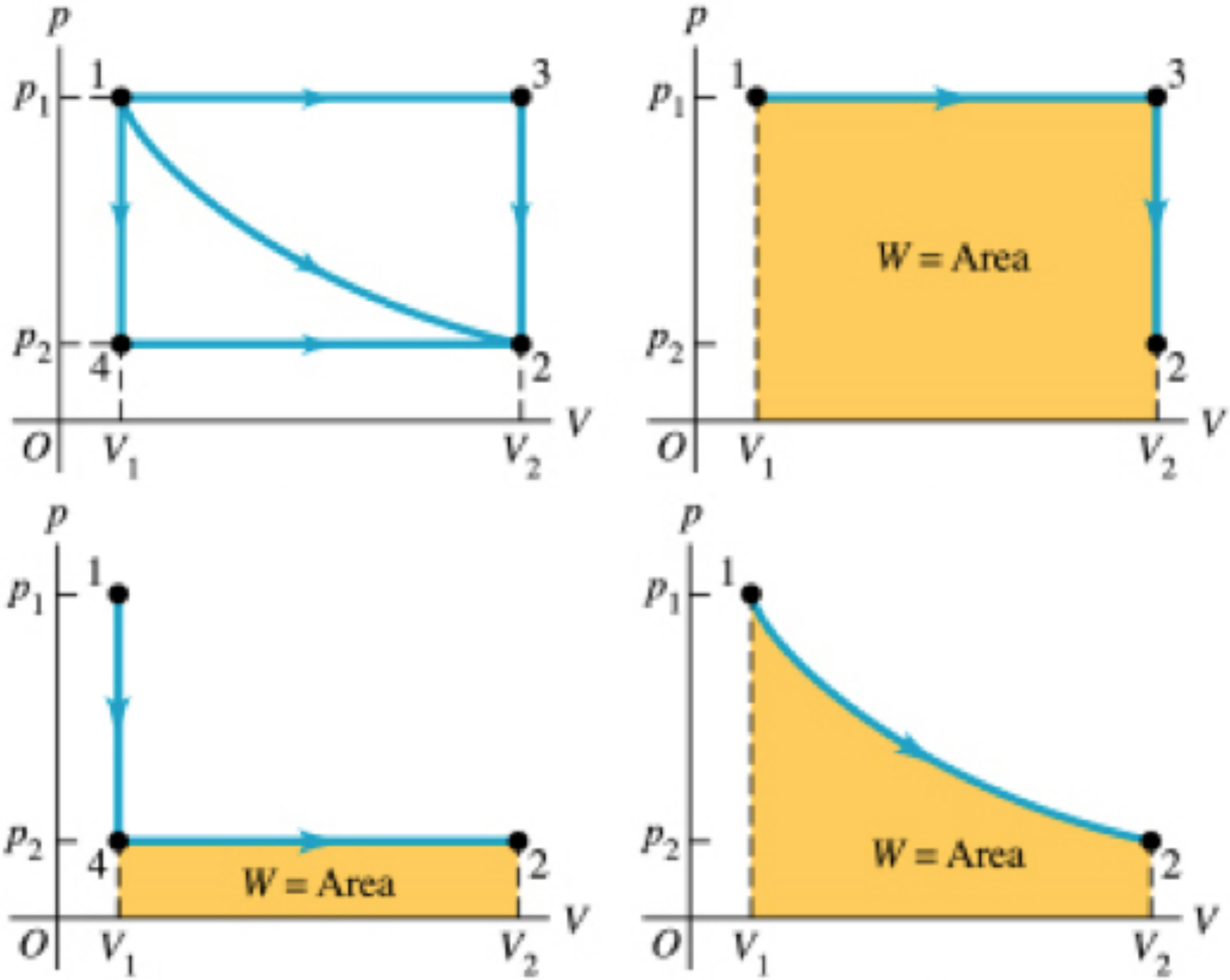


Expansion Work:

$$w = -P_{op}\,\Delta V$$

$$(w = -f\Delta x = -P_{op}A\Delta x = -P_{op}\,\Delta V)$$

Work (and heat): path dependent



For a **closed system**, the first law can be expressed as:

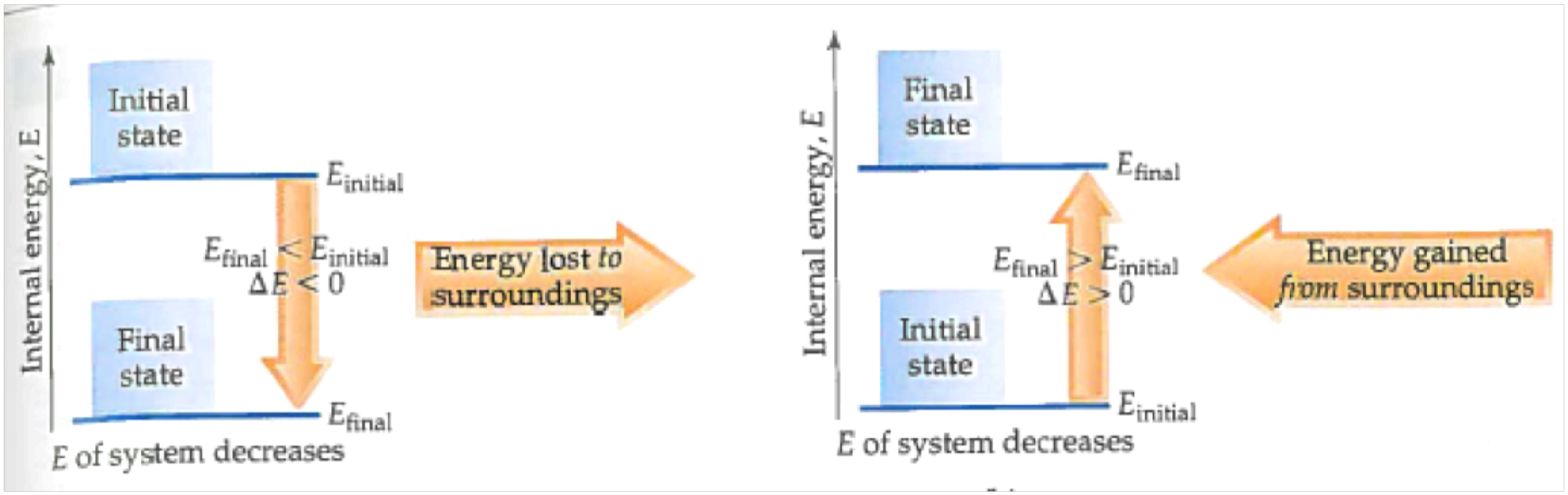
$$\Delta E = E_B - E_A = q + w$$

ΔE is the change in internal energy of the system.

Important!

***E* is a state variable and extensive property!**

***q* and *w* are not state functions (they are path dependent)**


Internal energy, E
Initial state
Final state
E_initial
E_final
E_final < E_initial
ΔE < 0
E of system decreases
Energy lost to surroundings
Internal energy, E
Final state
Initial state
E_final
E_initial
E_final > E_initial
ΔE > 0
E of system decreases
Energy gained from surroundings

Example

By how much does the energy of a system change after it does 40 kJ of work to the surroundings and absorbs 20 kJ of heat from the surroundings?

Clicker question 1

Which of these changes always results in an increase in the internal energy of the system?

A) The system absorbs heat and does work on the surroundings

B) The system releases heat and does work on the surroundings.

C) The system absorbs heat and has work done on it by the surroundings.

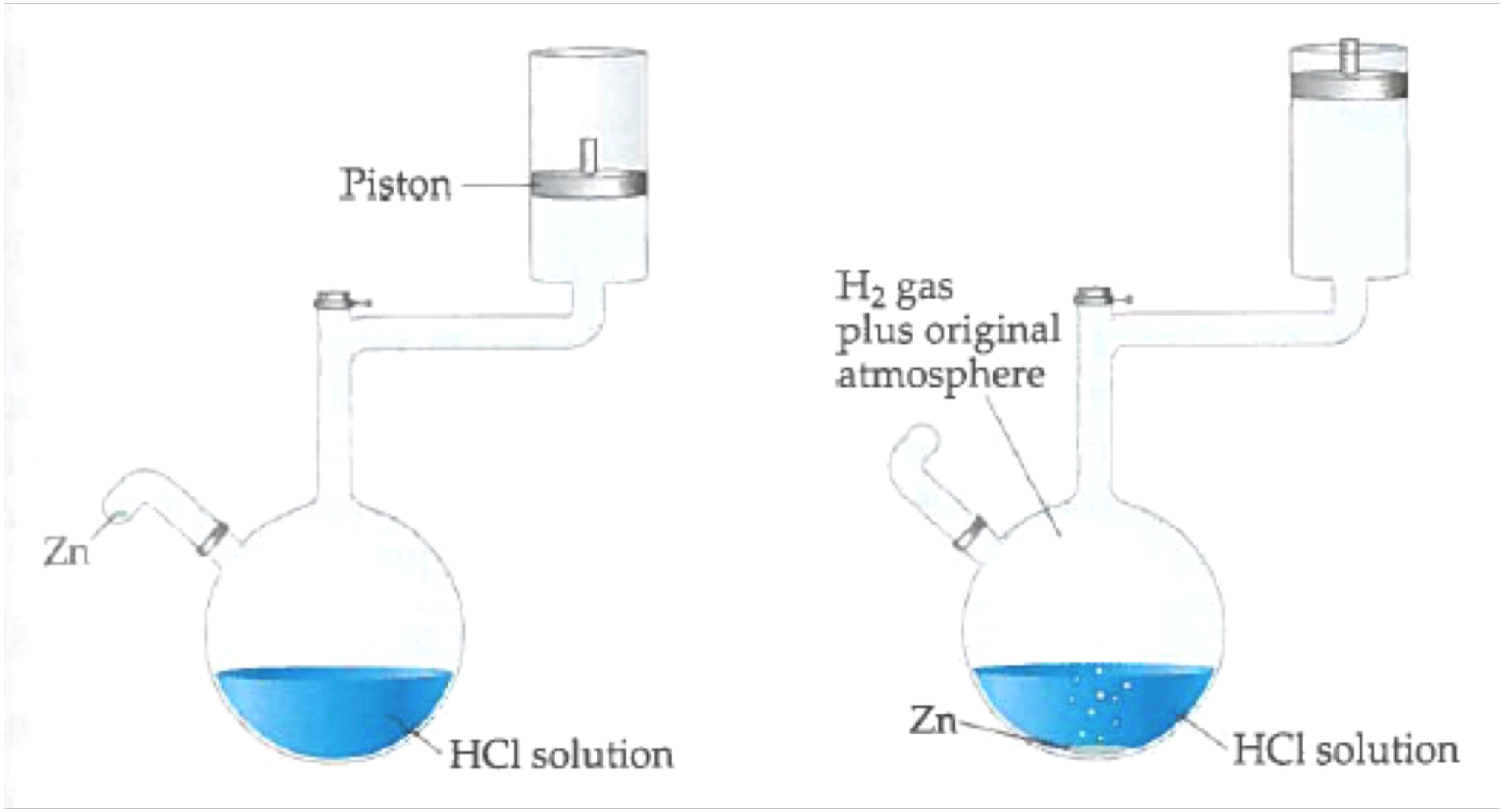
D) The system releases heat and has work done on it by the surroundings.

Clicker question 2

A system releases 300 J of heat and does 500 J of work on the surroundings. What is the change in the internal energy of the system?

A) +800 J
B) +200 J
C) -800 J
D) -200 J

Work in a chemical reaction



$$2NaN_3 \longrightarrow 3N_2 + 2Na$$

130 grams of sodium azide will produce 67 liters of nitrogen gas within 0.03 second!!!

How much work does airbag do to the surroundings?

$W=-p_{ex}V$

Chapter 3. The first Law of Thermodynamics
(p50-60)

Learning Objectives

By the end of this section, successful learners will be able to:

- Recognize enthalpy is a state variable
- Learn to determine ΔH from measured q and w
- Relate fluxes of work and heat under conditions of constant volume to state variables
- Relate fluxes of work and heat under conditions of constant pressure to state variables

Energy can be exchanged between a **closed system** and its surroundings in one of two ways:

1. Transfer of **Heat**
2. Exchange of **Work**

Heat *q*:

q is the amount of heat transferred between the system and the surroundings. $[q] = [\mathrm{J}]$ (Joules)

(δq stands for an infinitesimal amount of heat transferred)

$q > 0$: If heat is added to the system from the surroundings

$q < 0$: If the system releases heat to the surroundings

EXOTHERMIC Process: A process that releases heat into the surroundings. ($q<0$)

ENDOTHERMIC Process: A process that absorbs heat from the surroundings. ($q>0$)

Track heat changes during processes

$$\Delta E = q - P_{op}\Delta V$$

Under constant volume condition, PV work is zero. Therefore:

$$\Delta E = q_V + w = q_V$$

Heat exchange under a constant volume condition allows us to keep track of ΔE!!

- The change of internal energy under constant volume condition equals to the heat exchange between the system and its surroundings!

- What about under constant pressure condition?

So, the First Law of Thermodynamics for a system doing *PV* work:

$$\Delta E = q + w$$

$$\Delta E = q - P_{op}\Delta V$$

For a process at constant pressure $P_{op} = P$

$$\Delta E = q_P - P\Delta V$$

Rearrange this expression to write q_P as a function entirely of state variables.

$$q_P = \Delta E + P\Delta V = \Delta\left(E + PV\right)$$

What do you get if you abbreviate: $H = E + PV$?

$$q_P = \Delta H$$

Enthalpy: a new state function

$$H = E + PV$$

$$\Delta H = q_P$$

Heat exchange under a constant pressure condition allows us to keep track of ΔH!!

- The change of internal energy under constant volume condition equals to the heat exchange between the system and its surroundings! $\Delta E = q_V$
- The change of enthalpy under constant pressure condition equals to the heat exchange between the system and its surroundings! $\Delta H = q_p$