Notes for chem 101 lecture 7b
0) admin – Test 2 is on Feb 24 (Wed). 2 Furloughs are coming up: Fri Feb 19 and Mon Feb 22. The test will be on chapters 4-5. (stoichiometry). Review session will be on Tuesday Feb 23: 12-1 pm PS 607 (if available)
0a) Review guide has been emailed and also posted
0b) a practice problem set has been emailed and posted.
0d) attendance sheet

Last time: we finished: titration, dilutions
Questions on the test?

Today: Energy and chemistry:

Thermochemistry

Thermochemistry: study of energy and its flow.
(1) Energy= capacity to do work.
What is work? Force x distance
(from Physics: force = kg m/s^2)
mechanical energy:
Kinetic Energy energy that something has because it is moving

$KE = \frac{1}{2} mv^2$; m =mass, v =velocity

Potential Energy energy that something has because of its position.

For example, gravitational potential energy:

$PE = mgh$; m=mass, g=gravitational acceleration, h =height.

(2) units: Joule: $1J = 1 \frac{kg\ m^2}{s^2}$
calorie: 1 cal = 4.184 J
1kcal = 1 Cal (used in nutrition)
thus 1 Cal = 1 kcal = 1000 cal
= 4.184 kJ = 4184 J

(3) Law of conservation of energy: -energy can neither be created nor destroyed

-the total amount of energy in the universe is a constant
- but energy can be transformed from one form to another.
For example mechanical energy can be converted to heat energy....

In chemistry: the amount of heat transferred into a system plus the amount of work done on the system must result in a corresponding increase of internal energy in the system

(4) Concepts to learn: System and State:

1) **System** defined by a boundary, outside is the surrounding.

Eg. Reactants and products in a reaction is the system.
The solution around the reacting species is the environment.

a) types of systems: *open* system exchanges mass and energy w/surroundings;
closed system doesn't exchange matter but can exchange energy.
isolated system: no xΔ of E or m.

2) state = a set of conditions/parameters which describe the system;

example : state variables; pressure, volume, temperature and number of moles: p, V,T, n

a) change of state: state can change from one to another state; the path is not important.

In chemical systems, we speak of internal energy, E: What is the internal energy of a system?

Example: say the system is a gas of helium. E of system has to do with the KE of all the molecs. no potential energy usually. but if it's H_2 gas, we may also have to include vibrational energy, or even rotational energy and also the bond energy (stored in the bond).

(5) thermodynamics is more concerned with the macroscopic energy changes.
When a system (read chemical substances) reacts and releases energy to the surroundings, the ΔE is negative. (ie the system itself is losing energy). "EXO thermic".

When it gains energy from the surrounding, it is "Endothermic".
Practice:

A piece of paper burns, it feels hot. is burning process exo or endo?
What is the system? The paper going to CO_2 and water. Is the air around it part of the system?

ice melts as we warm it with our hands, is melting exo or endo? Again, what is the system? The ice. Surroundings? Our hands.
Ice + heat → water
We place water in the freezer. It freezes, is that process exo or endo??
System involves:

Water -> ice + heat

Surrounding: the freezer around it.

There are many forms of energy. Heat is one of them. Others: light, sound, mech energy.

2) In thermochemistry, we are interested in determining the change of energy of the form called "enthalpy". H. "heat content" of system. We can measure ΔH by calorimetry.

we can measure heat by measuring its effect on the temperature of a substance.

$Q = mC_p\Delta T$. m= mass of substance (in g) , C_p = specific heat (J/g°C). ΔT = change in temperature=(T_f-T_i)°C, Q= heat transferred (in J)

C_p = 1.0 cal/g°C for water. 1 cal = 4.18 J. (Joule is the SI unit of energy) (calorie was used for heat measurements. In nutrition, 1 Calorie = 1000 calories.

How many joules of energy are needed to raise the temperature of 31.0 g water from 23° to 88°C?

$Q = mC_p\Delta T = (31.0g)(4.18J/g°C)(88\text{-}23)°C = 8423$ J = 8.42 kJ (note:1kJ=1000J)

8) What is calorimetry? A technique used to measure T changes and to relate it to the Q. It is useful for determining the energetics of a reaction.

E.g. Suppose we add 20.0 mL of 1.0M HCl to 20 mL of 1.0 M NaOH and the temp of the mixture increases from 20°C to 23°C, what is the energy of the neutralization reaction (per mol H^+ neutralized)?

$Q = mC\Delta T$: m = mass of aqueous soln mixture, ≈ 20+20 =40 g why? (note: density=1g/mL for water)
C = 4.18 J/g°C (assume same as water). ΔT = 23-20 = +3°C
Q = (40)(4.18)(3)=501.6 J
(note that this is for neutralization of (MV=.020L x 1.0mol/L=.020 mol = 20 mmol H^+)
Per H^+ this would be: 501.6 J / .020mol = 25,080 J/mol = 25.1 kJ/mol

Let's go back and think of this example. This is a calorimetric example. It involves use of insulated container, heat released or absorbed is directly measured in the temp change of the water, no heat is lost or gained from the outside of the water since it is insulated.

In the above example, if that was the result of a chemical reaction occuring in the water, say:
A(aq) + B(aq) --> C(aq), we can think of the system as the molecs (or ions) of the solute, A, B and C and the water as the surroundings.

The reaction of A, B and C don't involve water directly. so, if we can determine how much heat was gained by the water (by measuring how much it heated up), then we can determine how much heat was given off by the reaction.

$q_{calorimeter} = -\Delta H$.

example: 25.0 mLs of 0.1 M HCl reacts with 25.0 mLs of 0.1M NaOH. Suppose that the solution temperature rises from 20°C to 22°C. What is the ΔH (in kJ/mol) for the neutralization reaction:
$HCl(aq) + NaOH(aq) \text{-->} NaCl(aq) + H_2O(l)$?

first, get $q_{cal} = mC\Delta T$ (m = 50.0 g if we assume density of soln = density of water = 1.0 g/mL)
C = 4.18 J/g°C if we assume that it is same as water.

so: $q_{cal} = (50.0)(4.18)(22-20)=418$ J

so, $\Delta H_{rxn} = -418.0$ J

But that is for the actual reaction. We need to determine it in a per mole basis: