February 3, 2017 Physics 132 Prof. E. F. Redish

- **Theme Music:** **Zimmer & Howard**
  Agent of Chaos **(from The Dark Knight)**
- **Cartoon:** **Mike Peters**
  Mother Goose & Grimm

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Energy conservation in chemical reactions

- A system has internal energy, U
- We break that down into thermal energy, $U_{thermal}$, and chemical energy $U_{chemical}$
- In a closed chemical reaction, the total energy stays the same, but goes back and forth between $U_{thermal}$ and $U_{chemical}$
- But energy could also go in or out of the system as heat or work.

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Changing our assumptions

- In each of our examples from the last class, we imagined a gas (or two gases) reacting in a closed container.
- While this is plausible – and relevant for many mechanical engineering example (the piston in the engine of an automobile, for example) in most biological situations, reactions occur at a constant pressure (in the open), not at a constant volume.
- What does that do to our energy conservation?

Why we need enthalpy

- When chemicals react in the open, they do so in a pressurized environment. They will expand or contract in order to maintain their pressure.
- In so doing, they will either do work on their environment or have work done on them.
- This will change the energy balance equation.

Recap: Partial pressure

- In a gas, pressure is produced by molecules hitting any surface introduced into it.

$$pV = Nk_BT \qquad p = nk_BT \qquad n = \frac{N}{V}$$

- If T is constant, p is directly proportional to n – the number density.
- Mixing many gases together, the pressure just adds the result of each molecule hitting the wall.
- The total p is the sum of the *partial pressures.*

$$p = p_1 + p_2 + ... = (n_1 + n_2 + ...)k_BT$$

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Foothold ideas: Enthalpy

- When a chemical reaction takes place at a **constant *T* and *p*** (especially in a gas), the gas may have to do work to "make room for itself". This affects the energy balance between the chemical energy change and the thermal energy change.
- Define *enthalpy, H*

$$\Delta H = \Delta U_{thermal} + \Delta U_{chemical} + p\Delta V$$

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Foothold ideas: Energy

- Kinds of energy (?)
  - Kinetic
  - Potential
  - Thermal
  - Chemical
- First law of thermodynamics
  - Conservation of total energy

Internal energy

Thermal energy entering

Work done on the rest of the world

$$\Delta U_{\text{int}} = Q - W$$

Energy needed to add internal energy at constant pressure (Enthalpy)

$$\Delta H = \Delta U + p\Delta V$$

We need to create a system schema for describing energy

- Consider a macroscopic object.
- Construct a system schema representation that shows the various places energy can reside in its internal structure (where "internal energy" can live).