Definition of chemistry sciences.

- *The science that study matter, changes that matter undergoes and the energy associate with these changes.*

Energy

- *Chemical energy represent the total amount of energy stored in the chemical particles and includes 2 forms work and heat.*
- *The capacity to do work or to produce heat.*
- *Law of conservation of energy – energy can be converted from one form to another but can be neither created nor destroyed.*
  - *The total energy content of the universe is constant.*

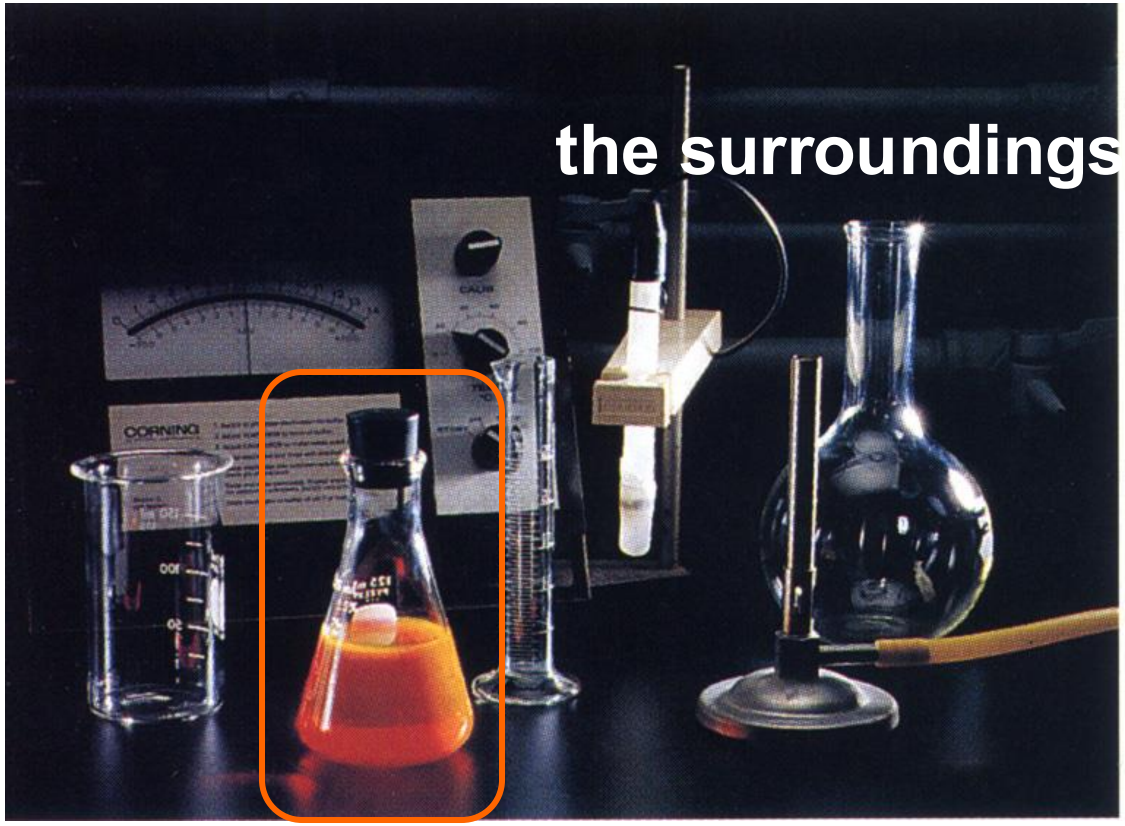
Energy

- *Heat involves the transfer of energy between two objects due to a temperature difference.*
- *Work – force acting over a distance.*

Chemical Energy

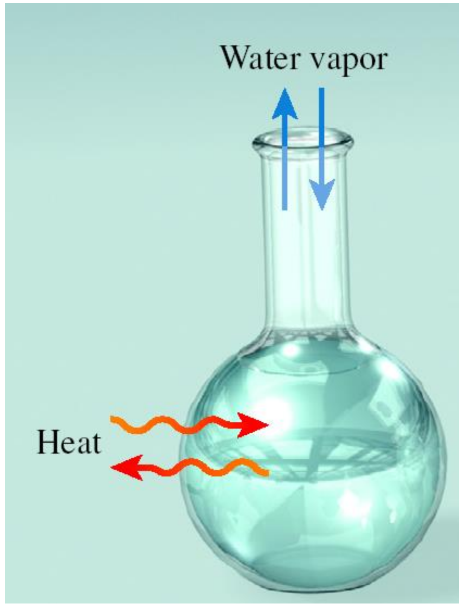
- *System – part of the universe on which we wish to focus attention.*
- *Surroundings – include everything else in the universe.*

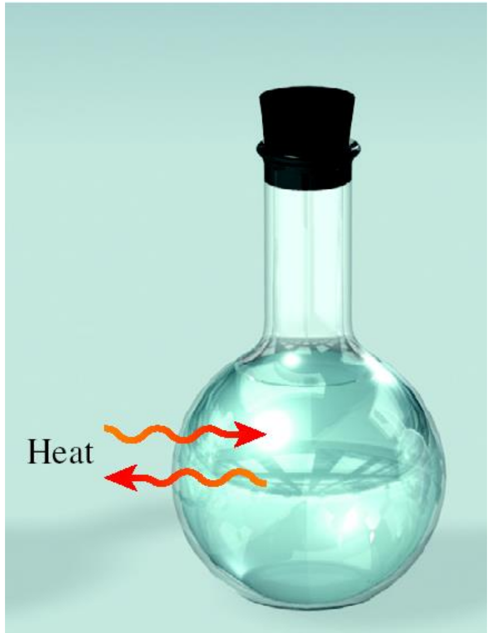
Chemical System and Surrounding



the system

- *Types of systems:*
  - ***open*** *(exchange of mass and energy)*
  - ***closed*** *(exchange of energy)*
  - ***isolated*** *(no exchange)*





Chemical Energy

- **Endothermic Reaction:**

  Heat flow is into a system.

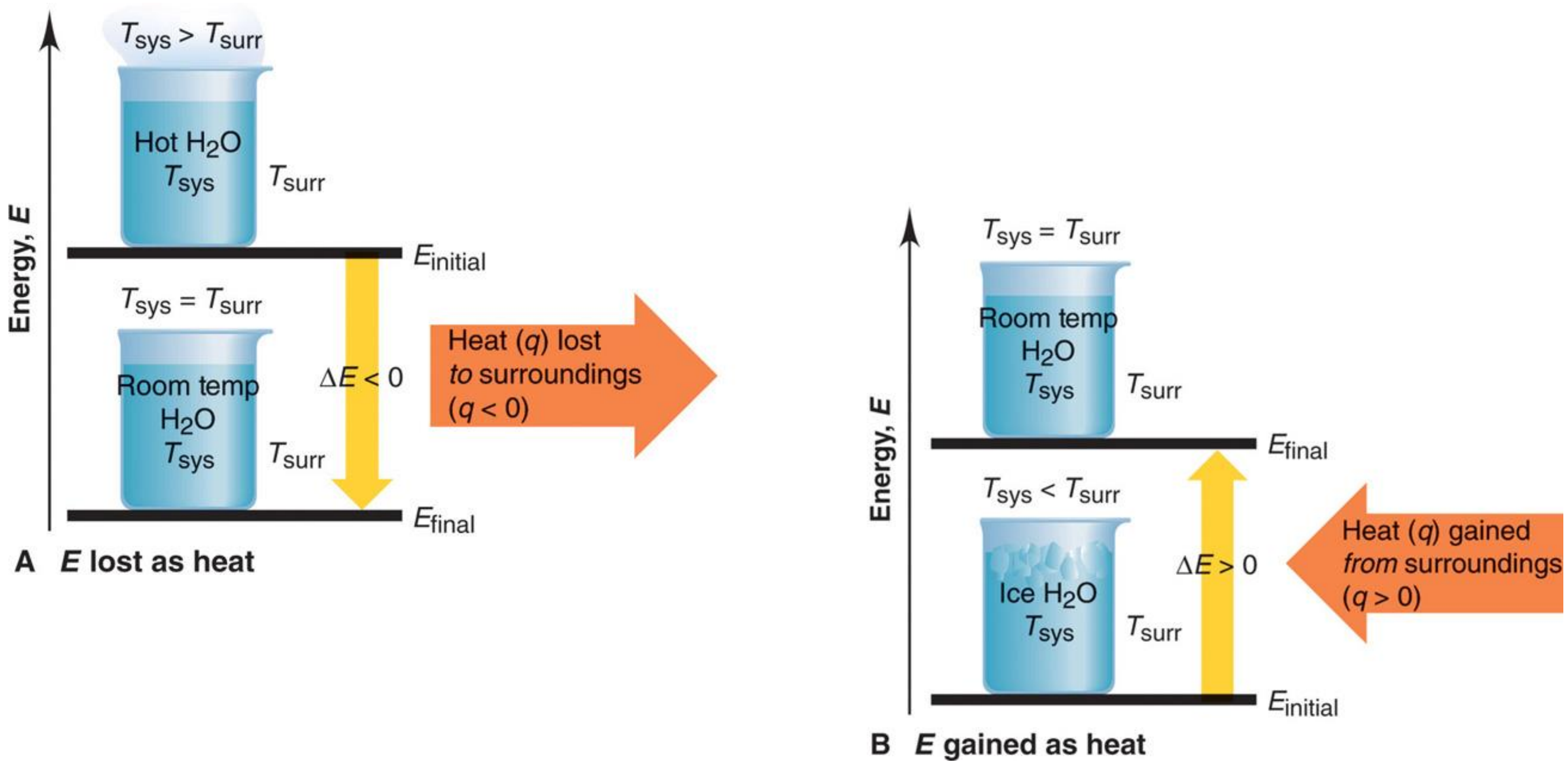
  Absorb energy from the surroundings.

Exothermic Reaction:

Energy flows out of the system.

Energy gained by the surroundings must be equal to the energy lost by the system.

Energy Transfer as heat



CONCEPT CHECK!

Is the freezing of water an endothermic or exothermic process? Explain.

CONCEPT CHECK!

Classify each process as exothermic or endothermic. Explain. The system is underlined in each example.

Exo a) *Your hand gets cold when you touch ice.*

Endo b) *The ice gets warmer when you touch it.*

Endo c) *Water boils in a kettle being heated on a stove*

Exo d) *Water vapor condenses on a cold pipe.*

Endo e) *Ice cream melts.*

CONCEPT CHECK!

For each of the following, define a system and its surroundings and give the direction of energy transfer.

a) *Methane is burning in a Bunsen burner in a laboratory.*

b) *Water drops, sitting on your skin after swimming, evaporate.*

CONCEPT CHECK!

Hydrogen gas and oxygen gas react violently to form water. Explain.

- *Which is lower in energy: a mixture of hydrogen and oxygen gases, or water?*

Thermodynamics

- *The study of energy and its interconversions is called thermodynamics.*
- *Law of conservation of energy is often called the first law of thermodynamics.*

Units of Energy

– ***Joule (J)*** *is the SI unit for energy.*
  - *The amount of energy possessed by a 2 kg mass moving at a speed of 1 m/s*

$$E_k = \tfrac{1}{2}mu^2 = \tfrac{1}{2}(2\ \text{kg})(1\ \text{m/s})^2 = 1 \text{kg} \cdot \text{m}^2/\text{s}^2 = 1\ \text{J}$$

$$1\ \text{J} = 1\ \text{N} \cdot \text{m} \qquad 1\ \text{N} = 1\ \text{kg} \cdot \text{m/s}^2$$

$$1\ \text{kJ} = 1000\ \text{J}$$

1cal=4.184 J

Internal Energy

- *Internal energy E of a system is the sum of the kinetic and potential energies of all the "particles" in the system.*

- *To change the internal energy of a system:* $\Delta E = q + w$

  q represents heat

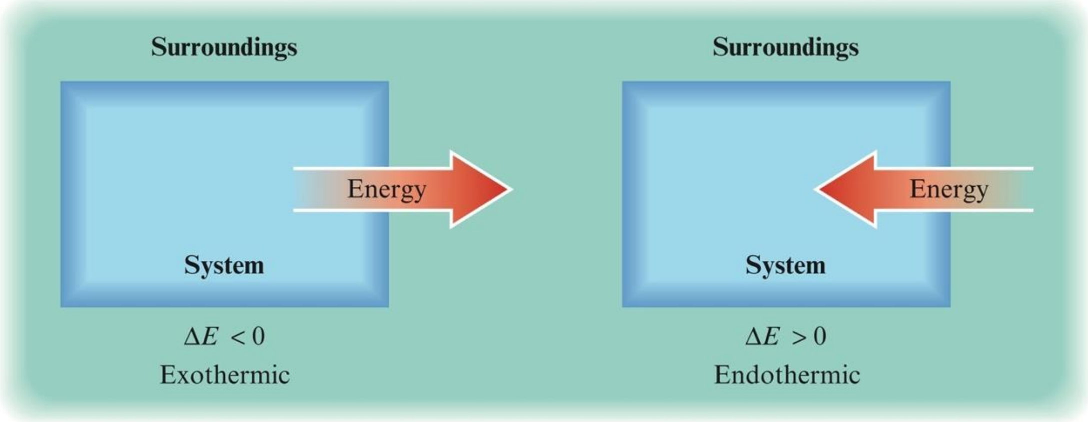
  w represents work

Internal Energy

- *Thermodynamic quantities consist of two parts:*
  - *Number gives the magnitude of the change.*
  - *Sign indicates the direction of the flow.*

Internal Energy

- *Sign reflects the system's point of view.*
- *Endothermic Process:*
  - *q is positive*
- *Exothermic Process:*
  - *q is negative*



Internal Energy

- *Sign reflects the system's point of view.*
- *System does work on surroundings:*
  - *w is negative*
- *Surroundings do work on the system:*
  - *w is positive*

CONCEPT CHECK!

Determine the sign of ΔE (Internal Energy) for each of the following with the listed conditions:

a) *An endothermic process that performs work.*

- $|work| > |heat|$ — Δ *E* = negative
- $|work| < |heat|$ — Δ *E* = positive

b) *Work is done on a gas and the process is exothermic.*

- $|work| > |heat|$
- $|work| < |heat|$

Δ *E* = positive

Δ *E* = negative

Calculate the overall change in internal energy for a system that absorbs 125 J of heat and does 141 J of work on the surroundings.

q is + (heat absorbed)

w is – (work done)

$$\Delta U_{sys} = q + w = (+125\ J) + (-141 J) = -16\ J$$

The system has lost 16 J of energy.

Calorimetry

- *Science of measuring heat*

$$q = ms\Delta T$$

$$q = C\Delta T$$

- C is heat capacity

q = *amount of heat (J)*

s = *specific heat capacity (J/° C·g)*

m = *mass of solution (g)*

ΔT = *change in temperature (° C)*

Calorimetry

- *Specific heat capacity (s):*
  The energy required to raise the temperature of one gram of a substance by one degree Celsius.

Heat capacity (C) :
The amount of heat required to raise the temp of an object by 1 ° C.

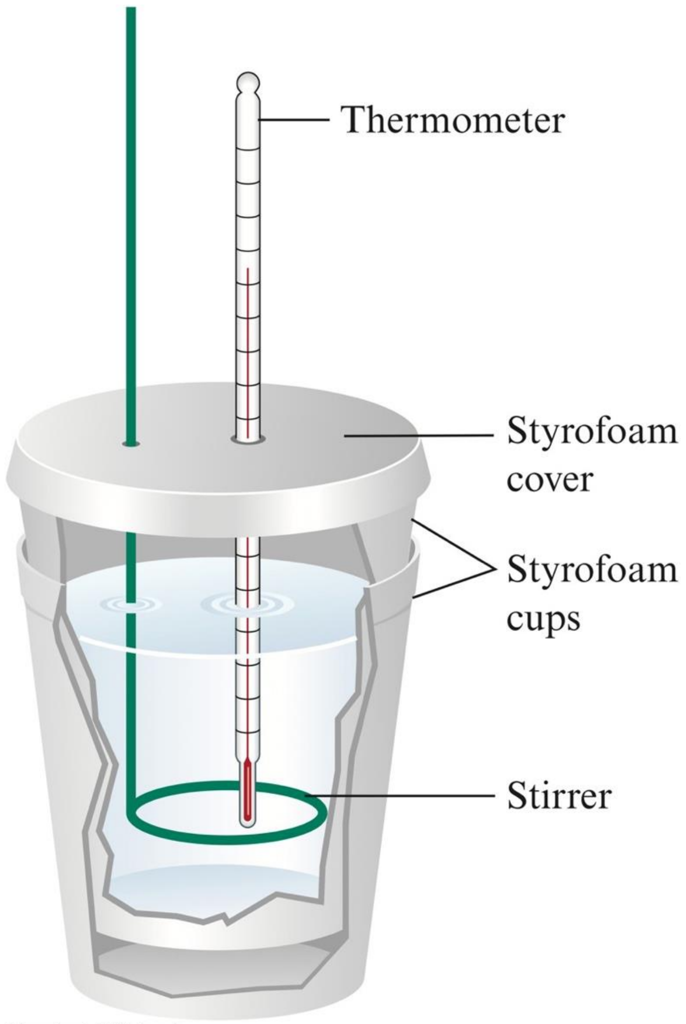
TABLE 5.2 Specific Heat Values of Some Common Substances

Substance	Specific Heat (J/g · °C)
Al(*s*)	0.900
Au(*s*)	0.129
C (graphite)	0.720
C (diamond)	0.502
Cu(*s*)	0.385
Fe(*s*)	0.444
Hg(*l*)	0.139
$H_2O(l)$	4.184
$C_2H_5OH(l)$ (ethanol)	2.46

Calorimetry

- *If two reactants at the same temperature are mixed and the resulting solution gets warmer, this means the reaction taking place is exothermic.*
- *An endothermic reaction cools the solution.*

A Coffee–Cup Calorimeter Made of Two Styrofoam Cups



Calculate the amount of energy required to heat 95.0 grams of water from 22.5□C to 95.5□C.

$$q = ms\Delta T$$

$\Delta T = T_{\text{final}} - T_{\text{initial}} = 95.5\ ^{o}\text{C} - 22.5^{o}\text{C}$

$\Delta T = 73.0\ ^{o}\text{C}$

$q = (95.0\ \text{g})\ (4.184\ \text{J/g}^{\circ}\text{C})\ (73.0^{\circ}\text{C})$

$q = 2.90 \times 10^{4}\ \text{J}$ or $29.0\ \text{kJ}$

CONCEPT CHECK!

A 100.0 g sample of water at 90° C is added to a 100.0 g sample of water at 10° C.

The final temperature of the water is:

- *a) Between 50° C and 90° C*
- *b) 50° C*
- *c) Between 10° C and 50° C*

CONCEPT CHECK!

A 100.0 g sample of water at 90.° C is added to a 500.0 g sample of water at 10.° C.

The final temperature of the water is:

- *a) Between 50° C and 90° C*
- *b) 50° C*
- *c) Between 10° C and 50° C*

Calculate the final temperature of the water.

23° C

CONCEPT CHECK!

You have a Styrofoam cup with 50.0 g of water at 10.° C. You add a 50.0 g iron ball at 90.° C to the water. ($s_{H2O} = 4.18$ J/° C·g and $s_{Fe} = 0.45$ J/° C·g)

The final temperature of the water is:

a) Between 50° C and 90° C

b) 50° C

c) Between 10° C and 50° C

Calculate the final temperature of the water.

18° C

- *Assume you have an iron ball with a mass 10g and temperature of 180C°. You dropped this ball inside a cup contains 100g water at 25C° . The final temperature of iron and water is 30C° . Given that S_{H2O}=4.184. calculate the iron specific heat S_{Fe}*

Enthalpy

- ***Enthalpy*** *is the internal energy plus the product of pressure and volume:*

$$H = E + PV$$

$$\Delta H = \Delta E + \Delta(PV)$$

$$\Delta H = \Delta E + P\,\Delta V$$ ***at constant pressure***

Enthalpy

$$\Delta H = \Delta E + P\,\Delta V$$

Since $\Delta E = q + w$, then

$$\Delta H = q + w + P\,\Delta V \qquad W = -P\Delta V$$

$$\Delta H = q \cancel{-P\Delta V} + \cancel{P\,\Delta V}$$

$$\Delta H = q$$

at constant pressure

Change in Enthalpy

- $\Delta H = q$ *at constant pressure*
- $\Delta H = H_{products} - H_{reactants}$
- *The unit of q is (J) while the unit of ΔH is (kJ/mole)*

- **ΔH is +** for endothermic changes.
- **ΔH is −** for exothermic changes.

- *Thermochemical Equations*
  - *Equations that represent both mols and enthalpy changes*

$$H_2O(s) \rightarrow H_2O(l) \quad \Delta H = +6.01\ kJ/mol$$

- *This is an endothermic process. It requires 6.01 kJ to melt one mole of ice, $H_2O(s)$.*
- *The enthalpy value will change if the number of moles varies from the 1:1 reaction stoichiometry.*

$$CH_4(g) + 2O_2(g) \longrightarrow CO_2(g) + 2H_2O(l) \qquad \Delta H = -890.4\ \text{kJ/mol}$$

- *This is an exothermic process. It releases 890.4 kJ when one mole of methane, CH_4, reacts.*
- *The enthalpy value will change if the number of moles varies from the 1:2:1:2 reaction stoichiometry.*

EXERCISE!

Consider the combustion of propane:

$$C_3H_8(g) + 5O_2(g) \rightarrow 3CO_2(g) + 4H_2O(l)$$

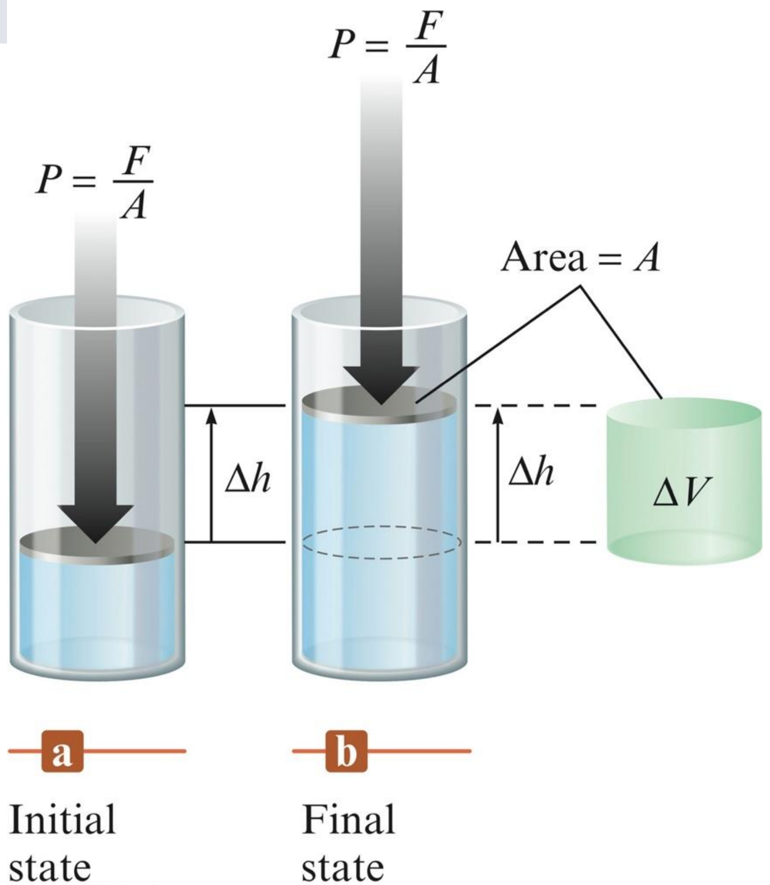
$$\Delta H = -2221\ kJ$$

Assume that all of the heat comes from the combustion of propane. Calculate the heat in which 5.00 g of propane is burned in excess oxygen at constant pressure.

–252 kJ

Work

- $Work = P \times A \times \Delta h = -P\Delta V$
  - *P is pressure.*
  - *A is area.*
  - *Δh is the piston moving a distance.*
  - *ΔV is the change in volume.*



Work

- *For an expanding gas, ΔV is a positive quantity because the volume is increasing. Thus ΔV and w must have opposite signs:*

$$w = -P\Delta V$$

- *To convert between L·atm and Joules, use 1 L·atm = 101.3 J.*

EXERCISE!

Which of the following performs more work?

a) *A gas expanding against a pressure of 2 atm from 1.0 L to 4.0 L.*

b) *A gas expanding against a pressure of 3 atm from 1.0 L to 3.0 L.*

They perform the same amount of work.

Sample Exercise 6.3 Internal Energy, Heat, and Work

A balloon is being inflated to its full extent by heating the air inside it. In the final stages of this process, the volume of the balloon changes from 4.00×10^6 L to 4.50×10^6 L by the addition of 1.3×10^8 J of energy as heat. Assuming that the balloon expands against a constant pressure of 1.0 atm, calculate ΔE for the process. (To convert between L · atm and J, use 1 L · atm = 101.3 J.)