Chemical Reactions & Equations

Chemical Energy (Heat) Thermodynamics

Dr. Ron Rusay

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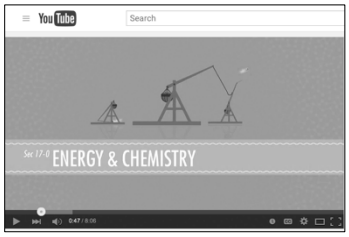


https://www.youtube.com/watch?v=RfzYl7Ll5Ug

Heat of Reaction & Heat Exchange

Exo- and Endo- thermic Reactions
(Exergonic and Endergonic)

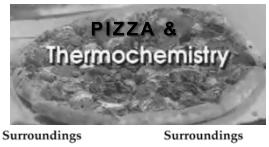
reactant(s) ⟶ product(s)

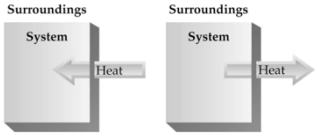
Two types of thermochemical reactions:

- *Exothermic: Heat is a reaction **product;** the heat flows to the surroundings. The amount is the difference between the products minus the reactants ….It is a negative value for the reaction.*
- *Endothermic: Heat is a **reactant;** the heat flows from the surroundings. The amount is the difference between the products minus the reactants…It is a positive value for the reaction.*

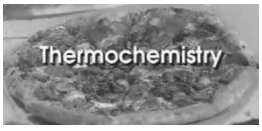
Temperature vs. Energy (Heat)

- *Temperature relates to the random motion of particles. If motion ceases, then in theory absolute zero (0 Kelvin) is possible.*
- *Heat of reaction involves transfer of energy due to the different energies of reactants and products. Temperature is not energy, but it relates to an energy state.*
  HOT (higher energy)→ cold (lower energy)





Why can you burn the top of your mouth with hot pizza just out of the oven and not the bottom?
(The top & bottom are at the same temperature!!!)



http://chemconnections.org/general/movies/Pizza-thermo%202.mp4

http://www.eia.gov/energyexplained/

Specific Heat Capacities

Substance	Specific Heat Capacity (J/g · K)*
Elements	
Aluminum, Al	0.900
Graphite, C	0.711
Iron, Fe	0.450
Copper, Cu	0.387
Gold, Au	0.129
Compounds	
Ammonia, $NH_3(l)$	4.70
Water, $H_2O(l)$	4.184
Ethyl alcohol, $C_2H_5OH(l)$	2.46
Ethylene glycol, $(CH_2OH)_2(l)$	2.42
Carbon tetrachloride, $CCl_4(l)$	0.862
Solid materials	
Wood	1.76
Cement	0.88
Glass	0.84
Granite	0.79
Steel	0.45

*At 298 K (25°C).

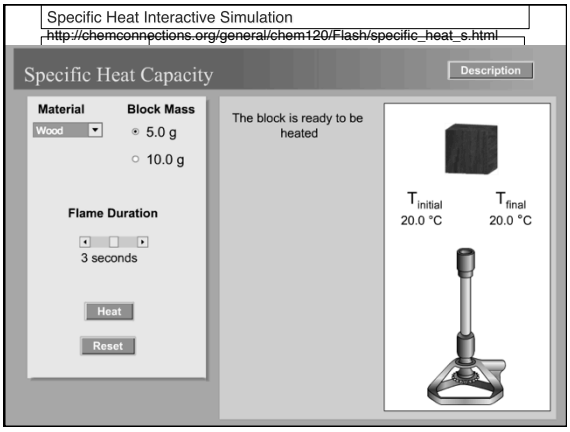
Cp UNITS:
J/(g·K)
or
J/(mol·K)

Energy :
joule (J)
calorie (c)
kilocalorie (C)
Kilowatt hour (kWh)

Light (radiant)
Motion (kinetic)
Electrical
Chemical
Nuclear energy
Gravitational

(Cp) Body fat: In obese mice (fat content 52.76% body wt) the heat capacity is **3.66** kJ kg-1 K-1 and in lean mice (fat content 7.55% body wt) the heat capacity is **2.65** kJ kg-1 K-1.

Specific Heat Interactive Simulation
http://chemconnections.org/general/chem120/Flash/specific_heat_s.html



QUESTION

The specific heat capacity of a sample that was claimed to be gold was determined. It required 48.8 J to raise the temperature of 15 grams of sample 25°C. Is the sample gold? (Use the value in the table on the previous slide, 0.13 J/g°C, for comparison.)

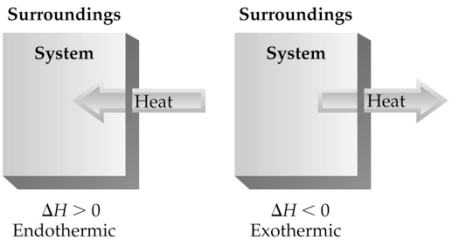
A. YES
B. NO
C. Cannot determine from the data.

Answer

The specific heat capacity of a sample that was claimed to be gold was determined. It required 48.8 J to raise the temperature of 15 grams of sample 25°C. Is the sample gold? (Use the value in the previous table, 0.13 J/g°C, for comparison.)

A. YES
B. NO
C. Cannot determine from the data.

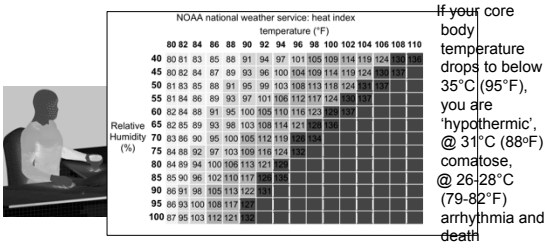
$0.13\ J/g°C = 48.8\ J / 15\ grams \cdot 25°C$



Human obesity (BMI >30) is associated with increased heat production; however, subcutaneous adipose tissue (fat) provides an insulating layer that impedes heat loss. This can be an advantage or a disadvantage depending on the surroundings. Do you know your Body Mass Index? See the NIH link below:

http://www.nhlbi.nih.gov/health/educational/lose_wt/BMI/bmi-m.htm

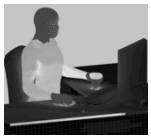
Thermoregulation: heat transfer to *or* from our body, and to *or* from the surroundings

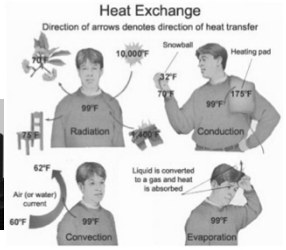


If your core body temperature drops to below 35°C (95°F), you are 'hypothermic', @ 31°C (88°F) comatose, @ 26-28°C (79-82°F) arrhythmia and death

Thermoregulation: heat transfer to or from our body, and to or from the surroundings

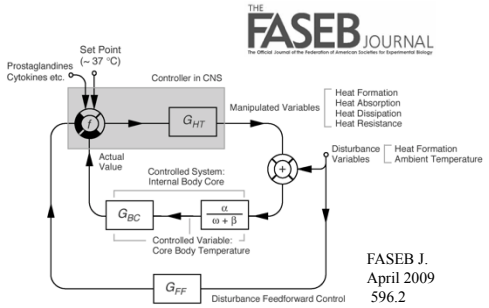
http://hyperphysics.phy-astr.gsu.edu/hbase/thermo/coobod.html#c1





If your core body temperature drops to below 35°C (95°F), you are 'hypothermic', 31°C (88ºF) comatose, 26-28°C (79-82°F) in arrhythmia and finally death

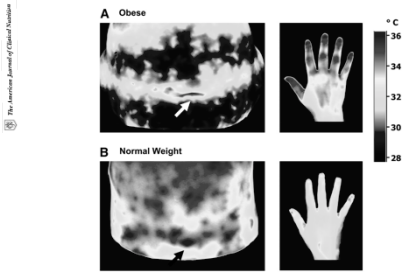
radiation, conduction, convection, evaporation



FASEB J. April 2009 596.2

The relative heat capacity (Cp) of an obese person (BMI >30) is higher than that of a lean person. It has a pronounced effect on thermoregulation and cooling of the body.

Abdominal (left) and right-hand (right) thermograms of an obese female (A) and a normal -weight female (B).

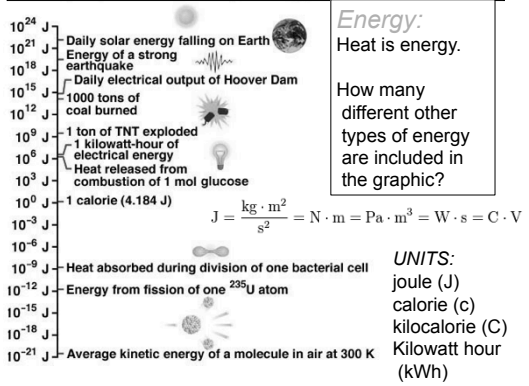


David M Savastano et al. Am J Clin Nutr 2009;90:1124-1131

Increased heat production is associated with obesity; however, subcutaneous adipose tissue provides an insulating layer particularly around the abdomen, which impedes heat loss. To regulate body temperature, obese individuals must increase their heat dissipation, one way is through their hands.

Two General Types of Energy

- *Potential: due to an object's position or material's composition - which can be converted to work*
- *Kinetic: due to motion of an object*
  - *KE = ½ mv²*
  - *(m = mass, v = velocity)*



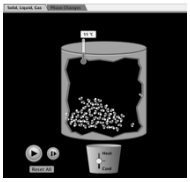
Energy:
Heat is energy.

How many different other types of energy are included in the graphic?

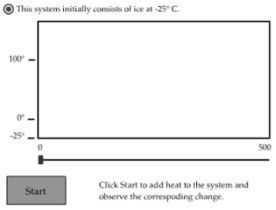
$$J = \frac{kg \cdot m^2}{s^2} = N \cdot m = Pa \cdot m^3 = W \cdot s = C \cdot V$$

UNITS:
joule (J)
calorie (c)
kilocalorie (C)
Kilowatt hour (kWh)

Substance	Specific Heat J / °C · g
$H_2O_{(l)}$	4.18
$H_2O_{(s)}$	2.03

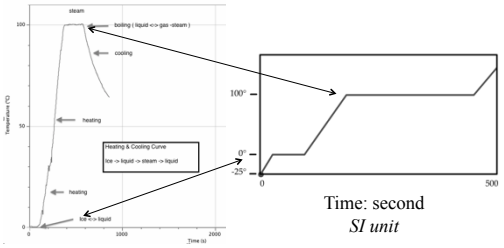


PhET/states-of-matter_en.jnlp



http://chemconnections.org/general/movies/HeatingCurves.swf

Temperature and Physical States
s ⇆ l ⇆ g



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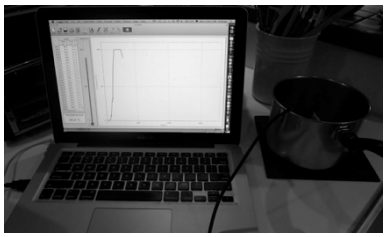
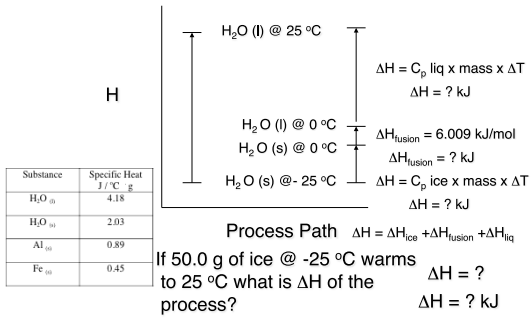


http://chemconnections.org/general/movies/HeatingCurves.swf

Heat @ constant Pressure (Enthalpy) ΔH
s ⇆ l ⇆ g

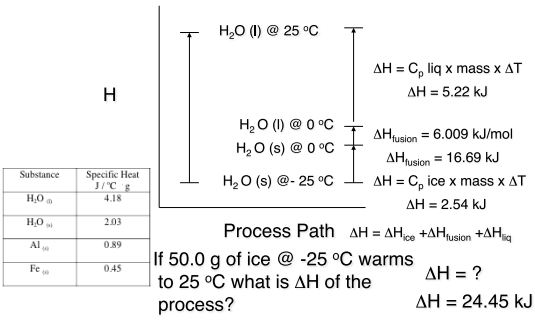


Substance	Specific Heat J / ºC g
$H_2O_{(l)}$	4.18
$H_2O_{(s)}$	2.03
$Al_{(s)}$	0.89
$Fe_{(s)}$	0.45

If 50.0 g of ice @ -25 ºC warms to 25 ºC what is ΔH of the process?

ΔH = ?
ΔH = ? kJ

Heat @ constant Pressure (Enthalpy) ΔH
s ⇆ l ⇆ g



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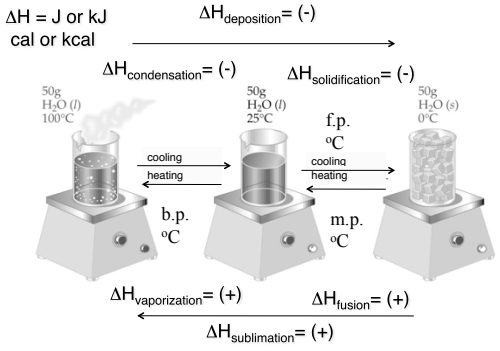
$H_2O_{(s)}$	2.03
$Al_{(s)}$	0.89
$Fe_{(s)}$	0.45

If 50.0 g of ice @ -25 ºC warms to 25 ºC what is ΔH of the process?

ΔH = ?
ΔH = 24.45 kJ



QUESTIONs

Answer either: A) endothermic, or: B) exothermic for each of the following 5 changes of physical state.

1. Fusion
2. Vaporization
3. Condensation
4. Sublimation
5. Liquid → Solid

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A) endothermic
ΔH_{fusion}= (+)

QUESTION

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A) endothermic
$\Delta H_{vaporization}$= (+)

QUESTION

Answer either: A) endothermic, or: B) exothermic for each of the following 5 changes of physical state.

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Answer

Answer either: A) endothermic, or: B) exothermic for each of the following 5 changes of physical state.

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3. Condensation
4. Sublimation
5. Liquid → Solid

B) exothermic
$\Delta H_{condensation}$= (-)

QUESTION

Answer either: A) endothermic, or: B) exothermic for each of the following 5 changes of physical state.

1. Fusion
2. Vaporization
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Answer

Answer either: A) endothermic, or: B) exothermic for each of the following 5 changes of physical state.

1. Fusion
2. Vaporization
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5. Liquid → Solid

A) endothermic

$\Delta H_{vaporization}$= (+) ΔH_{fusion}= (+)

$\Delta H_{sublimation}$= (+)

QUESTION

Answer either: A) endothermic, or: B) exothermic for each of the following 5 changes of physical state.

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Answer

Answer either: A) endothermic, or: B) exothermic for each of the following 5 changes of physical state.

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5. Liquid → Solid

B) exothermic

$\Delta H_{solidifcation}$= (-)

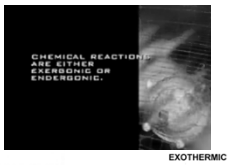
Heat of Reaction

The heat of any reaction can be calculated from the heat(s) of formation of products minus reactants.

- $\Delta H_{rxn}^\circ = \Sigma n_p \Delta H_f^\circ(products) - \Sigma n_r \Delta H_f^\circ(reactants)$

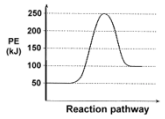
Endothermic ΔH_{rxn}°=(+) and Exothermic ΔH_{rxn}°=(-)

Heat of Reaction



Endergonic ΔH_{rxn}°=(+) and Exergonic ΔH_{rxn}°=(-)

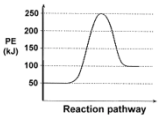
QUESTION



(True/False) The above energy diagram represents an exothermic reaction.

A. TRUE
B. FALSE

Answer



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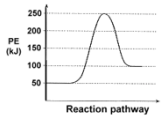
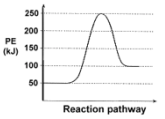
QUESTION



The heat of reaction represented in the above energy diagram is: _____ and is _____ .

A. +200 kJ and is endothermic
B. -200 kJ and is exothermic
C. +50 kJ and is endothermic
D. -50 kJ and is endothermic
E. -150 kJ and is exothermic

Answer



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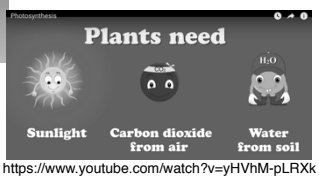
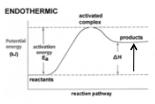
A. +200 kJ and is endothermic
B. -200 kJ and is exothermic
C. +50 kJ and is endothermic
D. -50 kJ and is endothermic
E. -150 kJ and is exothermic

Endothermic Reactions

Photosynthesis

6 $CO_{2\,(g)}$ + ***6*** $H_2O_{(l)}$ + *energy* ⟶ $C_6H_{12}O_{6\,(s)}$ + ***6*** $O_{2(g)}$





https://www.youtube.com/watch?v=yHVhM-pLRXk

$\Delta H_{rxn}^{\circ} = \Sigma n_p \Delta H_f^{\circ}(products) - \Sigma n_r \Delta H_f^{\circ}(reactants)$

$\Delta H_{rxn}^{\circ} = (+) = +2800$ kJ/mol $C_6H_{12}O_6$ *(glucose or fructose)*

https://www.youtube.com/watch?v=cOJ3MUpDrfI&index=2&list=PLE7B4FAD08F1EBCE2

Endothermic Reactions

$Ba(OH)_2 \cdot 8H_2O(s) + 2NH_4Cl(s) \rightarrow 2NH_3(g) + 10H_2O(l) + BaCl_2(s)$

http://chemconnections.org/general/movies/EndotermHMVID12.MOV

$\Delta H_{rxn}^{\circ} = \Sigma n_p \Delta H_f^{\circ}(products) - \Sigma n_r \Delta H_f^{\circ}(reactants)$

$\Delta H_{rxn}^{\circ} = (+) = +\ ?$ kJ/mol

QUESTION

Determine the heat of reaction for the reaction from the video. The respective total heats of formation for the total mass (total moles) of reactants is -3973 kJ and the total products is -3811 kJ. Also, identify if the reaction is exothermic or endothermic.

$Ba(OH)_2 \cdot 8H_2O(s) + 2NH_4Cl(s) \rightarrow 2NH_3(g) + 10H_2O(l) + BaCl_2(s)$

A. 7784 kJ, endothermic
B. -7784, exothermic
C. 162 kJ, endothermic
D. -162 kJ, endothermic
E. 162 kJ, exothermic

Answer

Determine the heat of reaction for the following reaction. The respective total heats of formation for the reactants is -3973 kJ and the total products is -3811 kJ. Also, identify if the reaction is exothermic or endothermic.

$Ba(OH)_2 \cdot 8H_2O(s) + 2NH_4Cl(s) \rightarrow 2NH_3(g) + 10H_2O(l) + BaCl_2(s)$

A. 7784 kJ, endothermic
B. -7784, exothermic
C. 162 kJ, endothermic
D. -162 kJ, endothermic
E. 162 kJ, exothermic

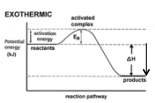
$\Delta H_{rxn}^\circ = \Sigma n_p \Delta H_f^\circ(products) - \Sigma n_r \Delta H_f^\circ(reactants)$

ΔH_{rxn}° = - 3811 kJ – (-3973 kJ) = + 162 kJ/mol

Exothermic Reactions

Glycolysis: ***Food*** */ eg.* ***"Burning" Sugar*** $\rightarrow$ *energy*
(Photosynthesis in Reverse)

$C_6H_{12}O_{6\,(s)} + 6\ O_{2(g)} \rightarrow 6\ CO_{2\,(g)} + 6\ H_2O_{(l)} + energy$



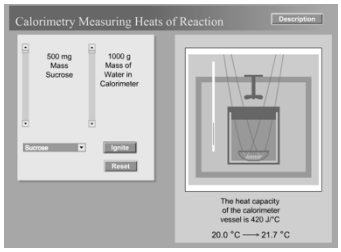
https://www.youtube.com/watch?v=EfGlznwfu9U

$\Delta H_{rxn}^\circ = \Sigma n_p \Delta H_f^\circ(products) - \Sigma n_r \Delta H_f^\circ(reactants)$

ΔH_{rxn}° = (-) = - 2800 kJ/mol $C_6H_{12}O_6$ *(glucose or fructose)*

Calorimetry (Interactive)

How much exercise do you need to burn 1 gram of sucrose?



m x Cp x ΔT = q

1000. g H_20 x 4.184 J/g°C x (1.7°C) =
= + 7100 J
= + 7100 J + 420 J

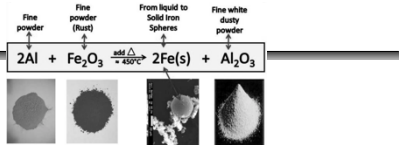
$\Delta H_{Reaction}$ = -7520 J / 0.500 g $_{sucrose}$

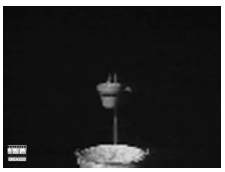
$\Delta H_{Reaction}$ = -15040 J / g $_{sucrose}$

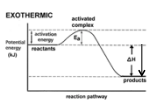
http://chemconnections.org/general/chem120/Flash/calorimetry_s.html

$\Delta H_{Reaction}$ = -15 kJ /g $_{sucrose}$ = -3.4 kcal /g $_{sucrose}$

Exothermic Reactions







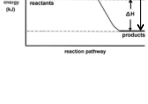
ΔH_{rxn}° = - 14,455 kJ/mol

http://www.youtube.com/watch?v=rdCsbZf1_Ng

Exothermic Reactions

Combustion: Burning Carbon Compounds

$C_xH_yO_z + (x + y/4 - z)\ O_2 \rightarrow x\ CO_2 + y/2\ H_2O + energy$

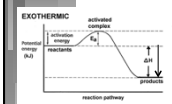


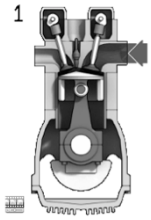
https://www.youtube.com/watch?v=UigjFAI2uWM

Exothermic Reactions

Octane (Gas) Combustion Engine

$$2\ C_8H_{18(l)} + 25\ O_{2(g)} \rightarrow 16\ CO_{2(g)} + 18\ H_2O_{(l)} + \text{energy}$$



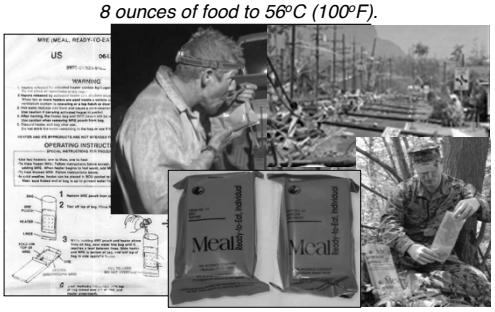


ΔH_{rxn}° = - 5,075 kJ/mol

http://chemconnections.org/general/movies/4StrokeEngine_Ortho_3D_Small.gif

Hot Food: MRE's Exothermic Reaction

Enough heat to raise the temperature of 8 ounces of food to 56°C (100°F).



$$Mg_{(s)} + 2\ H_2O_{(l)} \longrightarrow Mg(OH)_{2\ (aq)} + H_{2\ (g)} + \text{energy:}$$

Enough to raise the temperature of 8 ounces of food to 56°C (100°F).

MREs: Exothermic Reaction

To 56°C (100°F) from what temperature?

What is the room's and your respective temperature?