THERMOCHEMISTRY

Definitions to know:

Exothermic – a chemical reaction in which more energy is released than is required to break bonds in the initial reaction.

Endothermic – a chemical reaction in which a greater amount of energy is required to break existing bonds in the reactants than is released when the new bonds form in the product molecules.

Specific heat – the amount of heat require to raise the temperature of one gram of a given substance by one degree

Calorimetry – measuring the amount of heat released or absorbed during a physical or chemical process.

Enthalpy of reaction – the difference between the enthalpy of the substances that exist at the end of the reaction and the enthalpy of the substances present at the start.

Heat of fusion - The amount of **heat** required to convert a unit mass of a solid at its melting point into a liquid without an increase in temperature.

Heat of vaporization - The amount of **heat** required to convert a unit mass of a liquid at its boiling point into vapor without an increase in temperature.

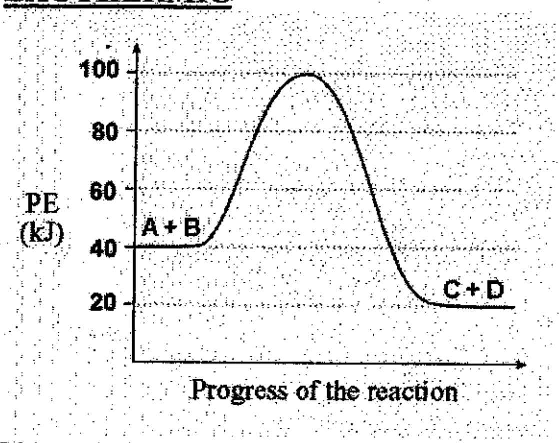
Calorimeter - An apparatus for measuring the amount of heat involved in a chemical reaction or other process.

Enthalpy of reaction = (enthalpy of products)-(enthalpy of reactants)

$\Delta H = \Delta H^{\circ}_f(\text{products}) - \Delta H^{\circ}_f(\text{reactants})$

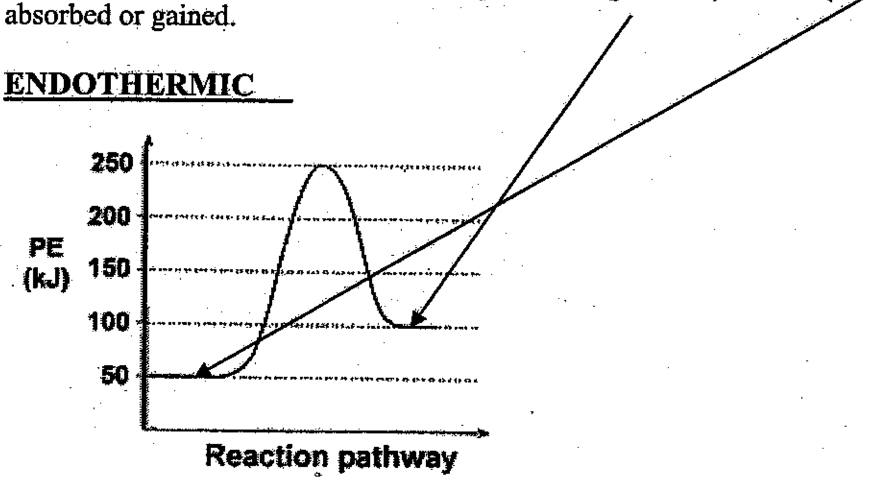
The equations below are used to calculate energy changes that occur in chemical reactions and to classify the reactions as exothermic or endothermic. An exothermic reaction is one in which is a release of heat; heat is given off. An endothermic reaction is one in which heat is absorbed; heat is taken in from the surroundings. The exothermic graph below shows how exothermic reactions give off heat. A+B are reactants and C+D are products. 20kJ – 40kJ = -20 kJ of energy are given off during this exothermic reaction.

EXOTHERMIC



This endothermic graph shows how endothermic reactions absorb or gain heat. Line before the curve represents reactants and line after curve represents products. (products)100kJ – (reactants)50kJ = +50 kJ of energy is absorbed or gained.

ENDOTHERMIC



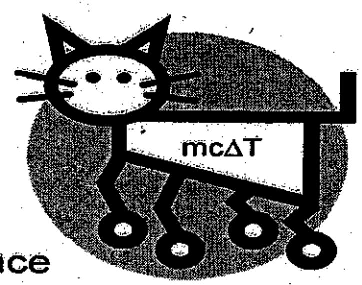
MORE THERMOCHEMISTRY

Calculating specific heat

Heat gained or lost = (mass)(specific heat)(change in temperature)
$Q = mc\Delta T$
Constants and Converstions
1 calorie (cal) = 4.18 joules (J)
1000 calories (cal) = 1 Calorie (Cal) = 1 kilocalorie (kcal)

Specific heat

$$q = mc\Delta T$$



where
- m = mass
- c = specific heat constant for a substance
- ΔT = change in temperature
- q = Heat

Heat lost by a substance = heat gained by a substance

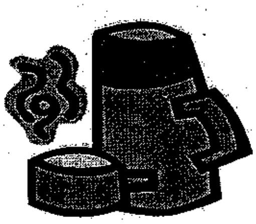
$$mc\Delta T_{(lost)} = mc\Delta T_{(gained)}$$

q is measured in Joules or kilojoules
c units are J / g°C
Temperature units are °C

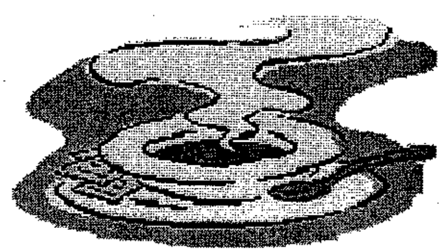
Specific Heat

Heat lost by one substance
=
heat gained by the other substance

$$mc\Delta T_{soup} = mc\Delta T_{spoon}$$



Example: a metal spoon or a china dish gains heat from soup or hot chocolate



Specific Heat Word Problem

1. How much heat energy is required to change the temperature of a ball of iron with a mass of 8052 grams from 16.5 ° C to a final temperature of 16.8 °C. The specific heat of iron is 0.451 J/g ° C.

FIRST STEP—Analyze the problem and decide on formula needed.

This is a specific heat problem—use $q = mc\Delta T$

SECOND STEP—List known and unknown

q iron = 0.451 J/g° C.

M iron = 8052 g

ΔT = 16.8 ° C– 16.5 ° C = 0.3 ° C

Unknown will be c (the amount of heat energy required).

THIRD STEP—Plug in values and calculate. Multiply across the top and divide by the bottom.

$$\frac{q}{m\Delta T} = c \qquad \frac{0.451\ \text{J}}{8052\ \text{g} \times 0.3\ ^\circ\text{C}} = c$$

FOURTH STEP—Check to see if your values seem reasonable, units are correct for your unknown, and significant figures are accounted for. Look for other possible errors, such as misplacing a decimal or misreading a number.

$$c = 0.176\ \frac{\text{J}}{\text{g}^\circ\ \text{C}}$$

Specific Heat Notes

1. Specific Heat is the amount of heat (measured in Joules or calories) needed to raise the temperature of one g of substance 1°C.
    i. Units on Specific Heat - J/g°C
2. Specific Heat is a physical property (a property you can observe without changing the molecules of the substance). The specific heat of a substance will always be the same.

3. Examples of Specific Heats:
    a. Water – 4.18 J/g°C
    b. Aluminum – 0.902 J/g°C
    c. Nickel – 0.444 J/g°C

   Which one of the substance will heat faster? Why?

4. Variables needed for the equation:
    a. Q = heat energy (measured in Joules)
    b. M = mass (measured in grams)
    c. C = Specific Heat (measured in J/g°C
    d. ΔT = change in Temperature (measured in °C)
       ΔT = Bigger temperature – Smaller Temperature

What variable is it?

Name	Variable Name	Variable Symbol	Name	Variable Name	Variable Symbol
1. 100 J			7. 21.5 g		
2. 0.87 J/g°C			8. 1.35 J/g°C		
3. 200 g			9. 14.1 °C		
4. 2.13 J/g°C			10. 25,000 J		
5. 585 J			11. 21 g		
6. 23.0 °C			12. 0.045 J/g°C		

Identify all the variables in the problem:

1) What is the specific heat of a substance that absorbs 2.5×10^3 joules of heat when a sample of 1.0×10^4 g of the substance increases in temperature from 10.0C to 70.0C?

2) The specific heat of ethanol is 2.46 J/g-°C. Find the heat required to raise the temperature of 193 g of ethanol from 19°C to 35°C.

How to calculate specific heat problems:

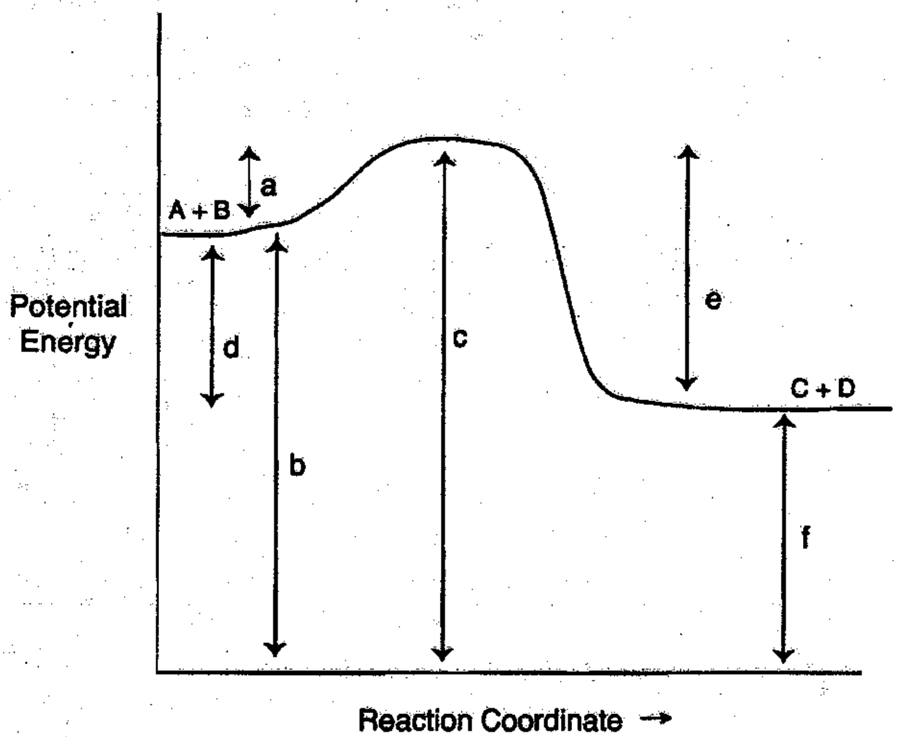
Formula: $Q = mc\Delta T$

1. When a 120 g sample of aluminum (Al) absorbs 9612 J of energy, its temperature increases from 25°C to 115°C. Find the specific heat of aluminum. Be sure to include the correct unit for specific heat.

2. The specific heat of lead (Pb) is 0.129 J/g-°C. Find the amount of heat released when 2.4 mol of lead are cooled from 37.2°C to 22.5°C

POTENTIAL ENERGY DIAGRAM

Name ______________



A + B ↔ C + D + energy

Answer the questions using the graph above.

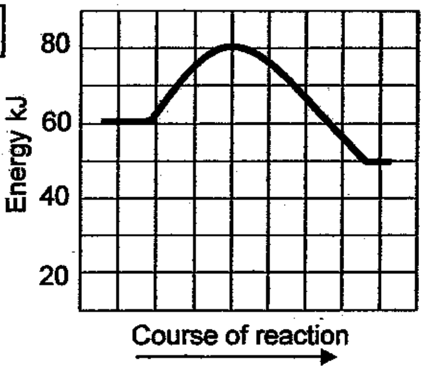
1. Is the above reaction endothermic or exothermic? ______________
2. What letter represents the potential energy of the reactants? __________
3. What letter represents the potential energy of the products? __________
4. What letter represents the heat of reaction (ΔH)? __________
5. What letter represents the activation energy of the forward reaction? __________
6. What letter represents the activation energy of the reverse reaction? __________
7. What letter represents the potential energy of the activated complex? __________
8. Is the reverse reaction endothermic or exothermic? ______________
9. If a catalyst were added, what letter(s) would change? ______________

Energy of Reactions 2013

For each of the following graphs, indicate the following:

a) Determine the ΔH of each reaction (the difference between beginning & ending energy. Show work.
b) Is the reaction exothermic (-ΔH) or endothermic (+ΔH) ?
c) Does it require activation energy (look for the "bump")? How much? Show work.
d) What is the net result of the change in heat energy? (Temperature does what? Will be opposite ofΔH)

1



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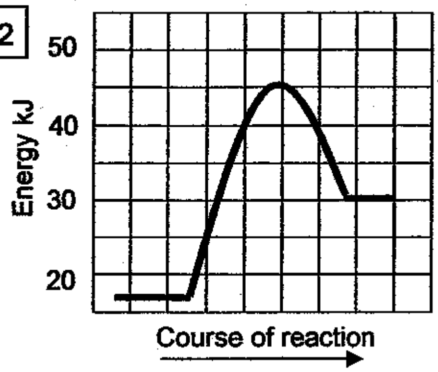

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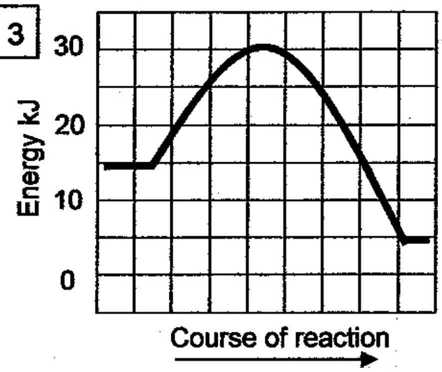

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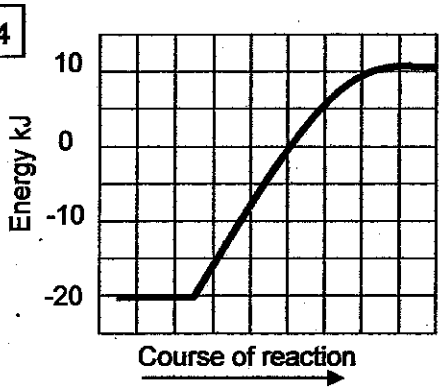

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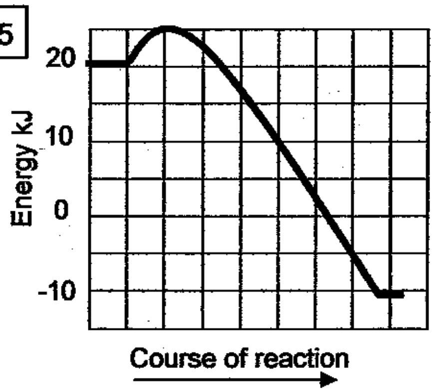

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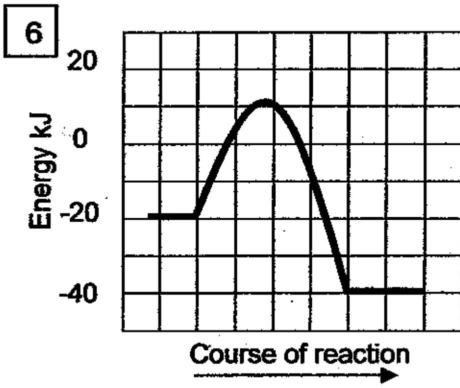

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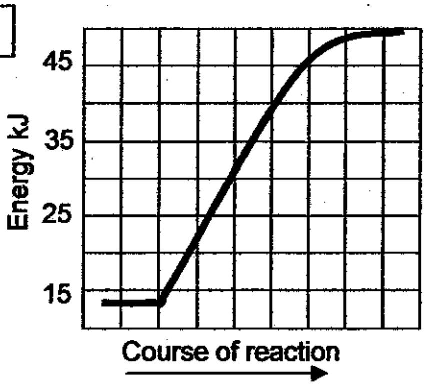

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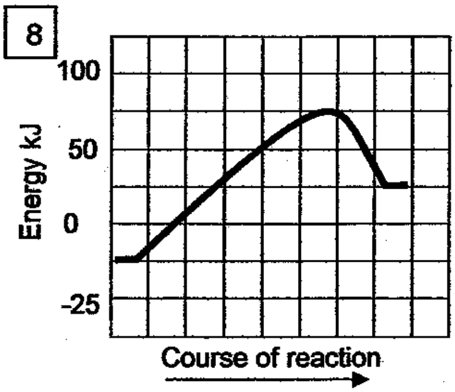

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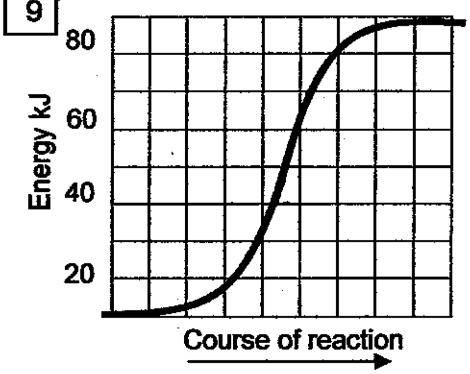

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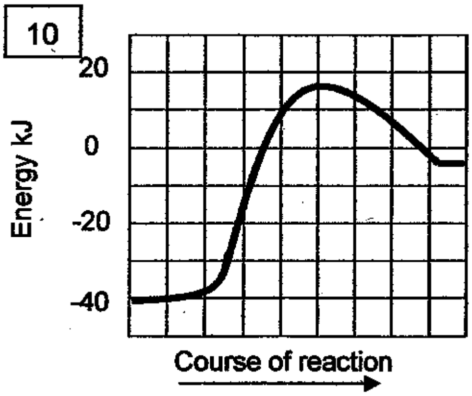

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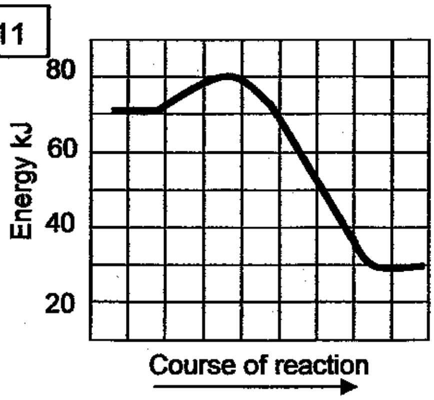

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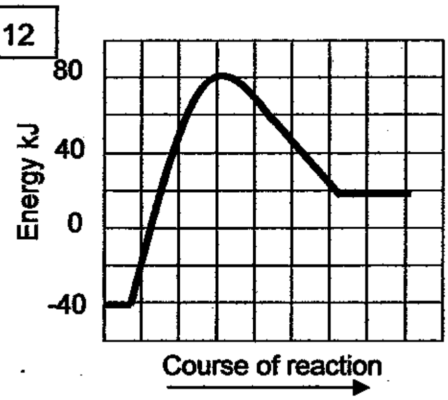


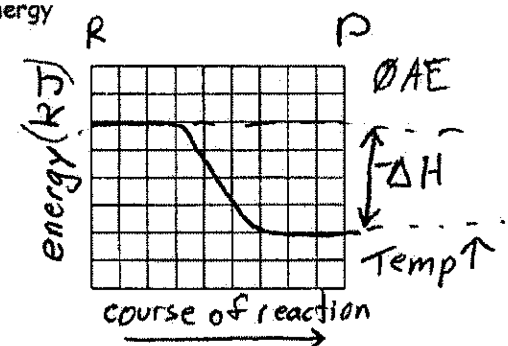
EXAMPLES

Drawing Energy of Reaction Graphs

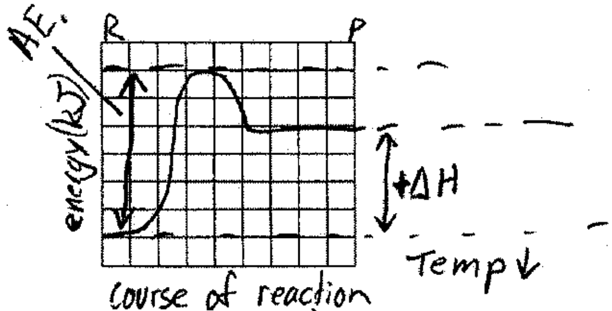
For each of the following examples, draw the appropriate corresponding graph of energy of the reaction.

a) Make sure to label both axis
b) Label the ΔH of each reaction.
c) Label the activation energy, if needed.

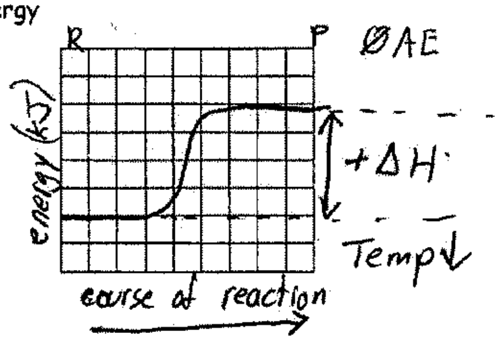
1. Exothermic reaction without activation energy



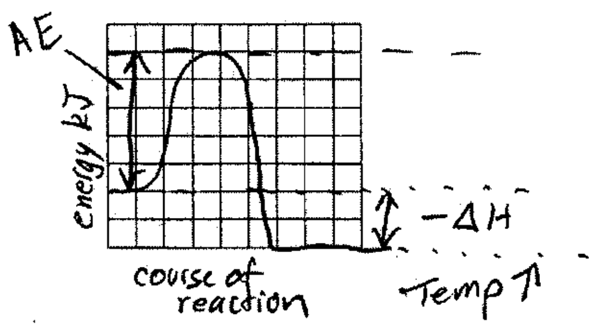
2. Endothermic reaction with activation energy



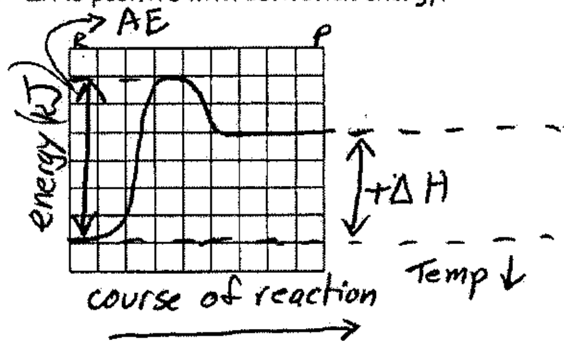
3. Temperature is decreased with no activation energy



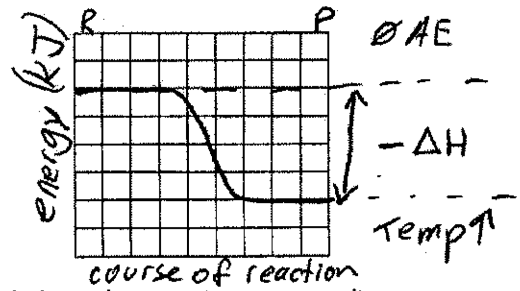
4. Temperature is increased with use of activation energy.



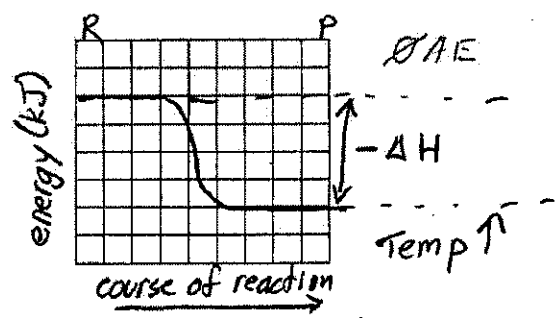
5. ΔH is positive with activation energy.



6. ΔH is negative without activation energy.



7. Released energy into surroundings.



8. Absorbs energy from surroundings.