My goal for unit 9 is...

How will you achieve this?

Page(s)...	Due on...

CHEMISTRY

Unit 09

Thermochemistry

Name ______________________________

Class Period ______

The UNIT 09 TEST is on

____

UNIT 9 Table of Contents

Don't wait until the day before the test to start the study guide!!!

Ask questions during class. Make corrections to your work!

Unit 09: Thermochemistry Units & Variables

Below you will find a list of all of the units/variables that will be used throughout this unit. It is in your best interest to **know these terms by definition as well as by their symbol and unit.** You should use the unit 9 quizlet (bit.ly/2Ov6mLc) to help familiarize you with these new terms and units/variables.

TERM	VARIABLE THAT REPRESENTS TERM	UNIT
Temperature	T	℃
Initial temperature	T_i	℃
Final temperature	T_f	℃
Change in temperature	ΔT	℃
Heat	q	J (or c calories)) (or kJ → 1 J = 0.001 kJ)
Heat absorbed	+q	J
Heat released	-q	J
Heat of the system	q_{sys}	J
Heat of the surroundings	q_{surr}	J
Mass	m	g
Specific heat	C	$\frac{J}{g°C}$
Enthalpy	H	J (or kJ)/mol
Change in enthalpy in an exothermic reaction	$- \Delta H$	J (or kJ)/mol
Change in enthalpy in an endothermic reaction	$+\Delta H$	J (or kJ)/mol
Heat of reaction	ΔH	J (or kJ)/mol
Molar heat of fusion	ΔH_{fus}	kJ/mol
Molar heat of solidification	ΔH_{solid}	kJ/mol
Molar heat of vaporization	ΔH_{vap}	kJ/mol
Molar heat of condensation	ΔH_{cond}	kJ/mol
Molar heat of solution	ΔH_{soln}	kJ/mol
Standard heat of formation	ΔH_f^0	kJ/mol

Unit 09: Thermochemistry Vocabulary

All of the following vocabulary words are relevant to the unit and are found on the Unit 9 Quizlet: bit.ly/3t09FsH

Thermochemistry - the study of energy changes that occur during chemical reactions and changes in state of matter

Chemical potential energy - the energy that is stored in the chemical bonds of a substance

Heat - (q) - energy that transfers from one object to another because of a difference in temperature between them

Temperature (℃) - a measure of the average kinetic energy of particles in matter; temperature determines the direction of heat transfer

System - the part of the universe on which you focus your attention, the point of reference.

Surroundings - everything in the universe outside of the chosen system

Law of conservation of energy - energy cannot be created or destroyed, it simply changes from one form to another during a chemical reaction

Endothermic reaction - a chemical reaction that requires heat in order to occur (heat is a reactant); the system (reaction) gains heat and the surroundings cool down

Exothermic reaction - a chemical reaction in heat is released (heat is a product); the system loses heat and the surrounds heat up

Calorie (c) - a unit for heat flow

Joule (J) - the SI unit of energy

Heat capacity - the amount of heat energy needed to increase the temperature of an object exactly 1℃; the heat capacity of an object depends on both its mass and its chemical composition

Specific heat (C) - the specific heat of a substance is the amount of heat energy it takes to raise the temperature of 1g of that substance 1℃. It can be calculated using the following formula:

$$C = \frac{q}{m\,\Delta T} = \frac{heat\ (J\ or\ c)}{mass\ (g)\ x\ change\ in\ temperature\ (^{\circ}C)}$$

Calorimetry - the precise measurement of the heat energy flowing into or out of a system for chemical and physical processes

Calorimeter - the insulated device used to measure the absorption or release of heat energy in chemical or physical processes

Enthalpy (H) - the heat energy content of a system at constant pressure

Change in enthalpy (ΔH) - the heat energy released or absorbed by a reaction at constant pressure **We will assume all reactions occur at constant pressure, so for this class, "heat" and "change in enthalpy" will mean the same thing**

Thermochemical equation - a chemical equation that includes the enthalpy change

Heat of reaction - the enthalpy change for the chemical equation exactly as it is written

Molar heat of combustion - the heat of reaction for the complete burning of one mole of a substance

Molar heat of fusion (ΔH_{fus}) - the amount of heat absorbed by one mole of a solid substance as it melts to a liquid at a constant temperature

Molar heat of solidification (ΔH_{solid}) - the amount of heat lost by one mole of a liquid as it solidifies at a constant temperature

Molar heat of vaporization (ΔH_{vap}) - the amount of heat absorbed by one mole of a liquid as it vaporizes at a constant temperature

Molar heat of condensation (ΔH_{cond}) - the amount of heat released by one mole of a vapor as it condenses to a liquid at a constant temperature

Molar heat of solution (ΔH_{soln}) - the enthalpy change caused by the dissolution of one mole of a substance

Hess's law - if you add two or more thermochemical equations to give a final equation, then you also add the heats of reaction to give the final heat of reaction

Standard heat of formation (ΔH_f^0) - the change in enthalpy that accompanies the formation of one mole of a compound from its elements with all substances in their standard states at 25°C

Standard heat of reaction (ΔH^0) - the difference between the standard heats of formation of all the reactants and products

For each of the formulas below, label the variables with their units and write a brief explanation of when you would use this formula.

$q = m\,C\,\Delta T$

$q_{system} - q_{surroundings} = 0$

$\Delta T = T_{final} - T_{initial}$

$\Delta H^o = \Sigma$ Bonds Energy(broken) - Σ Bond Energy (formed)

$\Delta H^o = \Sigma\, \Delta H^o_f$(products) - $\Sigma\, \Delta H^o_f$(reactants)

Use this page to take down notes for your one-pager or to add additional notes for other topics in the unit.

Topic / Objective: **Textbook 17.1 "The Flow of Energy -- Heat & Work" (Pages 505-510)**	Name: Date:
Essential Questions: **What is heat?**	
Questions:	Notes:
Summary:	

Heat Energy Notes & Practice

Name: ______________________________

Read & Annotate this! ___________ is the movement of matter. In order for atoms and molecules to move around and undergo a chemical reaction, there must be energy present. Energy exists in many forms… for example, you are probably very familiar with electrical energy, light energy and sound energy. Atoms and molecules have energy, too! The type of energy that is stored in chemical bonds is called chemical potential energy. When chemical bonds are broken or made during a chemical reaction, this potential energy can be turned into heat energy. As this energy transformation occurs, the atoms and molecules begin to move. Kinetic energy is the term that describes the energy of motion.

Energy Transformations

Heat is ALWAYS moving. Heat moves from ___________________ to __________________. When the temperature between two substances is equal, heat is still transferred between the substances, but it moves equally back and forth - there is no *net flow* of heat. This is known as thermal equilibrium. Let's take a closer look at the different ways we can describe the movement of heat...

HEAT	TEMPERATURE
• Is the _____________ of energy. • Moves from 1 object to another when there is a ________________ in ___________________. • Flows from ___________ temperature to _______ temperature. • Variable: _____ • Unit(s):	• Is a ___________________. • Measures average ________________ energy (_____________________) of particles in matter. • How _______ or _________ something is. • Determines ________________ of heat flow. • Variable: ______ • Unit(s):

SYSTEM	SURROUNDINGS
• Our point of _______________. (we pick it) • The part of the universe on which we ________ all of our attention. • In a chemical rxn, it will be the _________ /_______________ that are reacting.	• _________________ else in the _________________that is _______ the chosen system.

ENDOTHERMIC REACTION	EXOTHERMIC REACTION
• Endo- means "____________" • Heat moves from surroundings ________ the system. • Heat is a _______________. • System _____________ / _____________ / __________________ heat. • ______ • Memory Trick: Heat **ENters** the system in **ENdothermic** reactions.	• Exo- means "________________" • Heat moves _______________ the system to the surroundings • Heat is a _______________ • System __________ / ________________ / _______________ heat • ______ • Memory trick: Heat **EXits** the system in **EXothermic** reactions.

Do you remember the law of conservation of **mass**? What did it say?

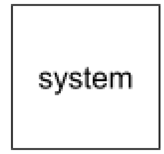
What do you suppose the law of conservation of **energy** (LOCOE) states?

How does LOCOE relate to heat transformations?

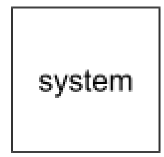
Practice

The box represents the system. Draw arrows to indicate the direction of heat flow.

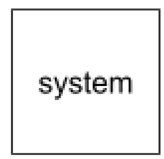
1) An ice cube is melting…
   a) What is the system? ____________________
   b) What are the surroundings? ____________________
   c) Exothermic or endothermic? *(circle one)*
   d) +q or -q? *(circle one)*



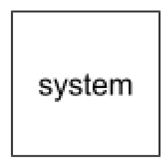
2) Melted candle wax begins to cool and solidify…
   a) What is the system? ____________________
   b) What are the surroundings? ____________________
   c) Exothermic or endothermic? *(circle one)*
   d) +q or -q? *(circle one)*



3) A log is placed into a bonfire and begins to burn…
   a) What is the system? ____________________
   b) What are the surroundings? ____________________
   c) Exothermic or endothermic? *(circle one)*
   d) +q or -q? *(circle one)*



4) Vinegar & baking soda are mixed together in a beaker and a reaction occurs. The beaker becomes cold.
   a) What is the system? ____________________
   b) What are the surroundings? ____________________
   c) Exothermic or endothermic? *(circle one)*
   d) +q or -q? *(circle one)*



The joule (J) is the SI unit for energy and the calorie (cal) is the english unit for energy. We can convert between these two units using the following conversion factor: *(1 J = 0.2390 cal)*. Use dimensional analysis for the following conversions…

5) How many calories are in 9.52 J?

(*2.28 cal*)

6) How many kilojoules are in 8.45 cal?
(1000 J = 1 kJ)

(*0.0354 kJ*)

Specific Heat Notes & Practice Name: ________________________________

Chemistry Date: __________________ Hour: _________

__________ (_____) is the energy that flows from one object to another because of a temperature difference. The amount of heat __________ or __________ by a substance can be calculated by using the **heat equation...**

$$\mathbf{q = m\,C\,\Delta T}$$

VARIABLE	DEFINITION	UNIT
q	____________	____________
m	____________	____________
C	____________	____________
ΔT	____________	____________

How to calculate ΔT:

Even though heat is always moving, objects don't change temperature at the same rate. The __________ __________ (____) of a substance is the amount of heat it takes to raise the temperature of 1 g of a substance 1℃. Based on its definition, it makes sense that specific heat is measured in units of __________. Specific heat is a __________ __________, which means it is a value that is unique for each substance. You can use the specific heat of a substance to determine its identity!

Metals transfer heat very quickly, so they have __________ specific heats while nonmetals, which take a long time to change temperature, have __________ specific heats. Which requires more energy to heat up?

Using $\mathbf{q = m\,C\,\Delta T}$

1) Identify knowns and unknowns with symbols and units
2) Write heat equation
3) Substitute known variables
4) Rearrange and solve for unknown

Endothermic signs & keywords

* q & ΔT
* ____________________
* ____________________
* ____________________
* ____________________
* ____________________

Exothermic signs & keywords

* q & ΔT
* ____________________
* ____________________
* ____________________
* ____________________
* ____________________

<u>In class practice</u>

1) Calculate the specific heat of titanium if a 43.56 g sample absorbs 476 J as its temperature changes from 20.13℃ to 41.06℃.

q =

m =

C =

ΔT =

2) A 40.0 g sample of ethanol **<u>releases</u>** 2952 J as it cools from 50.0 °C. Calculate the final temperature of the ethanol.The specific heat for ethanol is 2.46 $J/g℃$

q =

m =

C =

ΔT =

The heat equation can be used to determine if a reaction is endothermic or exothermic. Remember that -q represents __________ and +q represents __________ . Well, ΔT can also help us determine *endo*- versus *exo*-... An increase in temperature (_____) means the system gained heat and a decrease in temperature (_____) means heat was lost to the surroundings.

Practice

1) Using algebra, write an expression for **ΔT** by rearranging the above equation.

2) Using algebra, write an expression for **m** by rearranging the above equation.

3) Using algebra, write an expression for **c** by rearranging the above equation.

For each question, read the statement and select the best response. Circle your answer.

4) The amount of heat it takes to raise the temperature of 1 g of a substance 1°C is called its ___.
   a) heat capacity
   b) joule
   c) specific heat
   d) chemical potential energy

5) 125 J of heat is added to two different metals, metal A and metal B. Both metals are of equal mass and were initially at the same temperature. Metal B's final temperature was greater than metal A's final temperature. As a result of this observation ___.
   a) metal A's specific heat is larger than metal B's
   b) metal B's specific heat is larger than metal A's
   c) not enough information given

6) The specific heat of iron is 0.11 cal/g ×°C and water is 1.00 cal/g ×°C. On a warm summer day what would you rather stand barefoot on/in, a sewer cap made of iron or a puddle of water? Assume equal masses of each.
   a) sewer cap
   b) puddle of water

Why?!

7) The temperature in Lake Michigan won't reach a reasonable swimming temperature until about mid-summer. The reason for this observation is ___.
   a) the small specific heat of water
   b) the large specific heat of water
   c) the large mass of water
   d) both B & C

8) Gasoline's specific heat is approximately half of water's. If Lake Michigan was filled with gasoline instead of water, it would take a ___ amount of time to warm up Lake Michigan during the summer.
   a) shorter
   b) longer

Practice

*Solve for the missing variable. The answers for each question have been provided for you to self-check your progress. [HERE](shorturl.at/gAMX6) (*shorturl.at/gAMX6*) is the key with detailed calculations. Complete answers will include all work, the correct units, and will be rounded according to the rules of significant figures. Then, determine if the reaction is endothermic or exothermic. Circle your answer.*

1) *[EXO / ENDO]* A 15.75 g piece of iron absorbs 1086.75 joules of heat energy from a blowtorch, and its temperature changes from 25°C to 175°C. Calculate the specific heat of iron.

0.46 J/g°C

2) *[EXO / ENDO]* How many joules of heat energy does a flamethrower need to transfer to raise the temperature of 10.0 g of aluminum from 22°C to 55°C? The specific heat of aluminum is 0.90 J/g°C.

297 J
2 sig figs → 3.0 x 10^2 J

3) *[EXO / ENDO]* The specific heat of a piece of wood is 1.8 J/g°C. If 1500.0 g of the wood releases 67,500 joules of heat energy while burning, what is its change in temperature?

-25°C

4) *[EXO / ENDO]* 100.0 g of 4.0°C water is heated over a stovetop burner. Calculate the final temperature of the water after it absorbs 14,000 J of heat energy. The specific heat of water is 4.184 J/g°C.

37°C

5) *[EXO / ENDO]* Calculate the initial temperature of 25 g of mercury when it is heated over a bunsen burner to 155°C, and absorbs 0.455 kilojoules of heat energy in the process. The specific heat of mercury is 0.14 J/g°C. (1000 J = 1 kJ)

25°C

6) *[EXO / ENDO]* How much heat is released when 432 g of aluminum cools from 71.0 ºC to 18.0 ºC? Aluminum has a specific heat of 0.9025 J/gºC.

-20,700J

7) *[EXO / ENDO]* What mass of lead is needed to absorb 54,000J of energy if its temperature is to increase by only 2.5 ºC. The specific heat of lead is 0.1276 J/gºC.

170,000 g

Use the table to the right to help identify the substance described in Question #8…

8) *[EXO / ENDO]* A 0.30 g piece of melted metal is cooled and fashioned into a bracelet. The amount of heat energy transferred from the metal to the surroundings is 121.1 J. If the change in temperature was measured to be 1,062°C, what is the specific heat, and identity of the metal?

This reaction is *[endothermic / exothermic]*

SPECIFIC HEAT OF COMMON MATERIALS

MATERIAL	SPECIFIC HEAT (J/g°C)
Iron	0.45
Copper	0.38
Lead	0.13

0.38 J/g°C → Copper

Calorimetry Notes & Practice Name: ______________________________

Chemistry Date: ________________ Hour: ________

View [this video](shorturl.at/aeANR) (shorturl.at/aeANR)or use the [Calorimetry SLIDES](shorturl.at/dmrJ2) (shorturl.at/dmrJ2)to fill in the blanks below.

LOCOE (Review)

Energy cannot be _____________ or ______________, only _______________.

***THE HEAT LOST BY THE SYSTEM MUST EQUAL THE HEAT GAINED BY THE SURROUNDINGS & VICE VERSA. ***

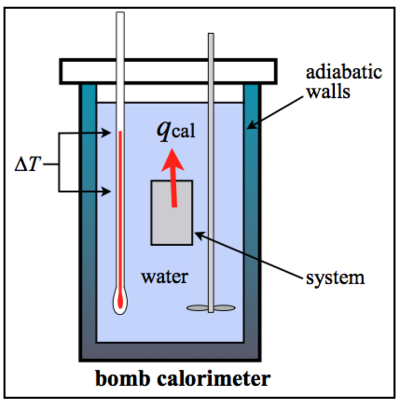
If we place the hot block of iron into water, the heat from the iron will be _______________ and _______________ by the water. This is a _________________ of energy.

We use the following equations: $-q_{system} = q_{surroundings}$ $q_{system} = -q_{surroundings}$ $q_{system} + q_{surroundings} = 0$

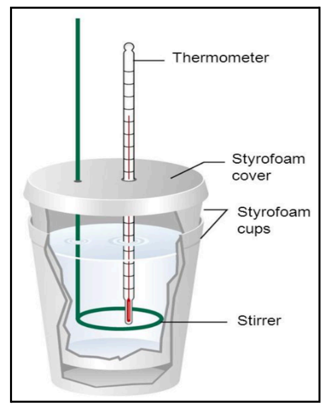
Calorimetry

Calorimetry is the measurement of __________ (q) flowing into or out of a ___________. It uses a _____________________ which is an insulated container that is used to measure ________ __________.

There are two types of calorimeters: A ___________ calorimeter and a __________ _______ calorimeter.



Both calorimeters function the same way and are built with the same basic structure: an ______________ container that can be filled with liquid, a _________________, and a stirrer. The container must be insulated in order to limit __________ _____________between the liquid in the chamber and the air in the _____________________.



In Class Practice

$q = mC\Delta T$ $\Delta T = T_f - T_i$ $C_{Water} = 4.184$ J/g°C $q_{sur} + q_{sys} = 0$ *1mL H_2O = 1g H_2O*

1) A metal is heated and placed in a calorimeter containing 14.0 g of water at 24.7 °C. The water reaches a maximum temperature of 40.2 °C. Calculate the heat, in calories, absorbed by the surroundings. *Use $q = m \cdot c \cdot \Delta T$ when information for one substance is given.*

 q =

 m =

 C =

 ΔT =

In Class Practice

$q = mC\Delta T$ $\Delta T = T_f - T_i$ $C_{Water} = 4.184$ J/g°C $q_{sur} + q_{sys} = 0$ 1mL H_2O = 1g H_2O

2) 4.5 grams of a metal is heated to 82.5 °C and placed in a calorimeter containing 14.0 g of water at 24.7 °C. The water and metal reach a maximum temperature of 40.2 °C. Calculate the specific heat of the metal (C_{metal}). *Use* $-(m \cdot c \cdot \Delta T)_{lost} = (m \cdot c \cdot \Delta T)_{gained}$ *when information for two substances given.*

m_{system}		$m_{surroundings}$	
C_{system}		$C_{surroundings}$	
$T_{initial, system}$		$T_{initial, surroundings}$	
$T_{final, system}$		$T_{final, surroundings}$	
ΔT_{system}		$\Delta T_{surroundings}$	
q_{system}		$q_{surroundings}$	

Practice

Complete answers will include all work, the correct units, and will be rounded according to the rules of significant figures. Then, determine if the system *is endothermic or exothermic. Circle your answer.*

$q = mC\Delta T$ $\Delta T = T_f - T_i$ $C_{Water} = 4.184\ J/g°C$ $q_{sur} + q_{sys} = 0$ $1mL\ H_2O = 1g\ H_2O$

1) A small pebble is heated and placed in a foam cup calorimeter containing 25.0 mL of water at 25.0°C. The water reaches a maximum temperature of 26.4°C. How many joules of heat energy were released by the pebble?

The system is *[endothermic / exothermic]*

-146 J

2) A piece of lead metal is heated and placed in a foam cup calorimeter containing 40.0 mL of water at 17.0°C. The water reaches a temperature of 20.0°C. How many joules of heat energy were released/absorbed by the lead?

The system is *[endothermic / exothermic]*

-502 J

3) A 3.00×10^2 g piece of iron was heated to 87.5°C and placed in a calorimeter that contained 123 g of water at 10.0 °C. The final temperature of the iron and water was 60.5 C. Calculate the specific heat of iron.

m_{system}		$m_{surroundings}$	
C_{system}		$C_{surroundings}$	
$T_{initial, system}$		$T_{initial, surroundings}$	
$T_{final, system}$		$T_{final, surroundings}$	
ΔT_{system}		$\Delta T_{surroundings}$	
q_{system}		$q_{surroundings}$	

The system is *[endothermic / exothermic]*

3.21 J/g°C

4) A piece of metal with a mass of 59.04 g was heated to 100.0 °C and then placed in a calorimeter containing 100.0 g of water at 23.7 °C. The metal and water were allowed to come to thermal equilibrium at 27.8 °C. Calculate the specific heat of the metal.

m_{system}		$m_{surroundings}$	
C_{system}		$C_{surroundings}$	
$T_{initial, system}$		$T_{initial, surroundings}$	
$T_{final, system}$		$T_{final, surroundings}$	
ΔT_{system}		$\Delta T_{surroundings}$	
q_{system}		$q_{surroundings}$	

The system is *[endothermic / exothermic]*

0.404 J/g°C

5) A piece of iron (C_{iron} = 0.460 J/g×°C) with unknown mass was heated to 87.5° C and placed in a calorimeter that contained 123 g of water (C_{water} = 4.184 J/g×°C) at 10.0 ° C. The final temperature of both the iron and water was 60.5° C. Calculate the mass of iron used.

m_{system}		$m_{surroundings}$	
C_{system}		$C_{surroundings}$	
$T_{initial, system}$		$T_{initial, surroundings}$	
$T_{final, system}$		$T_{final, surroundings}$	
ΔT_{system}		$\Delta T_{surroundings}$	
q_{system}		$q_{surroundings}$	

The system is *[endothermic / exothermic]*

2090 g

6) CHALLENGE: A piece of copper (C_{copper} = 0.092 cal/g×°C) of mass 19.0 g was heated to 87.4° C and placed in a calorimeter that contained 55.5 g of water at 18.3° C. The final temperature of both the water and the copper was 20.4° C. Calculate the specific heat of water from this process. *HINT: Pay attention to your units!*

m_{system}		$m_{surroundings}$	
C_{system}		$C_{surroundings}$	
$T_{initial, system}$		$T_{initial, surroundings}$	
$T_{final, system}$		$T_{final, surroundings}$	
ΔT_{system}		$\Delta T_{surroundings}$	
q_{system}		$q_{surroundings}$	

The system is *[endothermic / exothermic]*

1.00 cal/g°C

Thermochemical Equations Notes

Name: ___________________________________

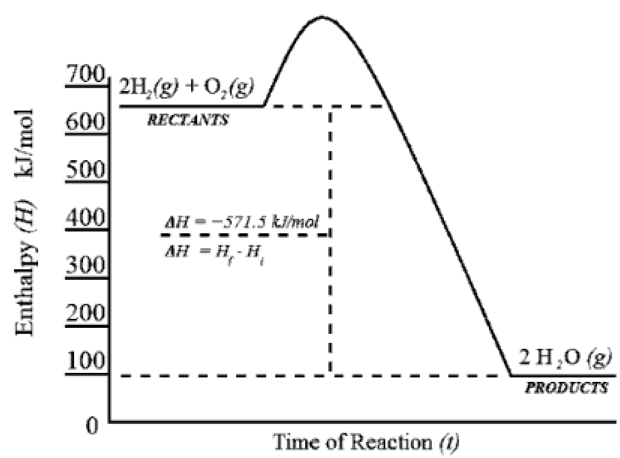
Chemistry

Date: ____________________ Hour: __________

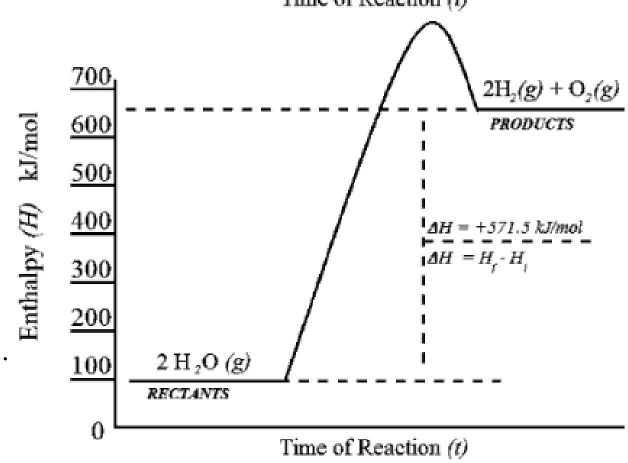
A bit of review…

- We know that every chemical and physical change obeys 2 fundamental laws:
  - LAW OF CONSERVATION OF ____________ (LOCOM)
    - Equations need to be ___________________
  - LAW OF CONSERVATION OF _____________ (LOCOE)
    - Chemical reactions either ______________ (_______) or _______________ (______) energy.
- What are thermochemical equations?
  - Balanced chemical equations that include the _______________ ______ ____________ content (_________)
  - THIS "HEAT CONTENT" IS CALLED _________________ (_____).
- What is enthalpy (H)?
  - Describes the ____________ __________ ________________ (<u>absorbed</u> or <u>released</u>) of a chemical reaction.
    - For our class, we can say that ______________.
  - Measured in units of _______ (kilojoules) or ___________ (kilojoules per mole)
  - Cannot measure just enthalpy, can only measure a _______________ (_____) in enthalpy (_____)
    - ΔH = "change in" enthalpy (_________ = ____________ - ____________)
  - ΔH = amount of __________ absorbed or released in a ______________ ______________ *(@ a constant pressure)*
  - _________ = energy changes that have been measured at "__________________ ____________________".
    - *ΔH° - pronounced "delta H naught"* *Standard conditions = 25 ºC & 1 atm*

Enthalpy Diagrams



- Graphic representations of the change of heat energy of a chemical reaction.
- Can be used to calculate ______
- Exothermic Enthalpy Diagram
  - $2 H_2(g) + O_2 (g) \rightarrow 2 H_2O (g) +$ _____________
  - $2 H_2(g) + O_2 (g) \rightarrow 2H_2O (g)$ *ΔH* = ______________
  - *ΔH* = H_f - H_i
  - Products have ________ energy than reactants.
  - "______________" appearance



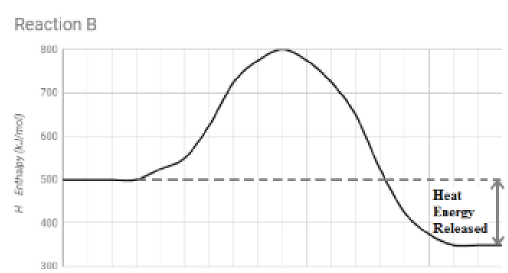
- Endothermic Enthalpy Diagram
  - $2 H_2O(g) +$ _____________ $\rightarrow 2 H_2 (g) + O_2 (g)$
  - $2 H_2O(g) \rightarrow 2 H_2 (g) + O_2 (g)$ *Δ* H = ______________
  - *ΔH* = H_f - H_i
  - Products have ________ energy than reactants.
  - Climbing ______ a hill _____________ _____________..

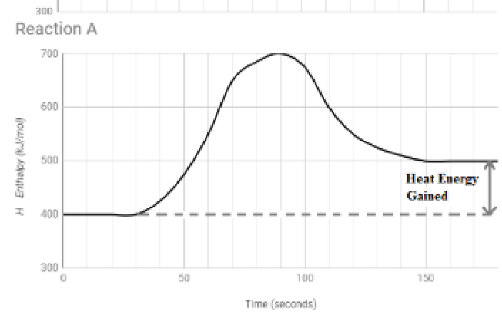
Thermochemical Equations

- ________________ chemical equations that include the _____________ _____ ____________ content (ΔH) . . .
- We can list the heat as…
    - a _______________ or a _______________in the chemical equation:
        - *Example:* **27 kJ** + $NH_4NO_3(s)$ → $NH_4^+(aq)$ + $NO_3^-(aq)$
    - a ΔH value listed ____________ to the chemical equation:
        - *Example:* $NH_4NO_3\,(s)$ → $NH_4^+\,(aq)$ + $NO_3^-\,(aq)$ ΔH = **+27 kJ/mol**
- Exothermic Reactions
    - Heat energy is __________________ (_____)
    - The system will ____________________ in temperature (_____),
    - The enthalpy change is ___________________ (_______).
    - Energy is ________________________, so it is a ___________________.
    - The formation of water is <u>exo</u>thermic. It __________________ energy. *There are 2 different ways to write it.*
        - Heat as a _______________ in the chemical reaction:
            - $2\ H_2(g) + O_2\ (g) \rightarrow 2\ H_2O\ (g)$ + _______________
        - Heat written next to the equation with a _________________ sign.
            - $2\ H_2(g) + O_2\ (g) \rightarrow 2\ H_2O\ (g)$ *Δ*H = _____________________
- Endothermic Reactions
    - Heat energy is __________________ (_____)
    - The system will ____________________ in temperature (_____),
    - The enthalpy change is ___________________ (_______).
    - Energy is ________________________, so it is a ___________________.
    - The decomposition of water is <u>endo</u>thermic. It _____________ energy. *There are 2 different ways to write it.*
        - Heat as a _______________ in the chemical reaction:
            - $2\ H_2O(g)$ + _________________ → $2\ H_2\ (g) + O_2\ (g)$
        - Heat written next to the equation with a _________________ sign.
            - $2\ H_2O(g) \rightarrow 2\ H_2\ (g) + O_2\ (g)$ *Δ*H = ____________________

<u>Summary</u>

- Exothermic -q -*Δ*H -*Δ*T
    - Energy **released** Heat is a **product**
    - Example equations
        - $2\ H_2(g) + O_2\ (g) \rightarrow 2\ H_2O\ (g)$ + **571.5 kJ**
        - $2\ H_2(g) + O_2\ (g) \rightarrow 2\ H_2O\ (g)$ *Δ*H = **-571.5 kJ/mol**
- Endothermic +q +*Δ*H +*Δ*T
    - Energy **absorbed** Heat is a **reactant**
    - Example equations:
        - $2\ H_2O(g)$ + **571.5 kJ** → $2\ H_2\ (g) + O_2\ (g)$
        - $2\ H_2O(g) \rightarrow 2\ H_2\ (g) + O_2\ (g)$ *Δ*H = **+571.5 kJ/mol**





Thermochemical Equations Practice with Stoichiometry

Chemistry

Name: ______________________________

Date: __________________ Hour: _________

1. When ethanol (C_2H_5OH) is burned, it reacts with oxygen (O_2). It also releases 1,368 kJ of heat energy to the surroundings and produces CO_2 gas and H_2O gas.

   a. Complete and balance the chemical equation below. ***Remember to include heat!***

   $$\_\_1\_\_\_\_ \; C_2H_5OH(l) + \_\_\_\_\_\_ \; O_2(g) \rightarrow \_\_\_\_\_\_ \; CO_2(g) + \_\_\_\_\_\_ \; H_2O(g)$$

   b. Calculate how much heat energy (in kJ) is released when 12.5 moles of ethanol burns.

   -17,100 kJ

   c. Calculate how many moles of carbon dioxide are produced if 787 kJ of heat energy are produced.

   1.15 mol CO_2

   d. Calculate how much heat energy (in kJ) is released when 124.7 grams of oxygen are reacted.

   -1777 kJ

2. Carbon dioxide (CO_2) and solid calcium oxide (CaO) are produced when solid calcium carbonate ($CaCO_3$) absorbs 177.8 kJ of heat energy.

   a. Complete and balance the chemical equation below. ***Remember to include heat!***

   $$\_\_\_\_\_\_ \; CaCO_3(s) \rightarrow \_\_\_\_\_\_ \; CO_2(g) + \_\_\_\_\_\_ \; CaO(s)$$

   b. Calculate how many moles of calcium oxide (CaO) is produced when 345 kJ of heat energy is gained.

   1.94 mol CaO

   c. Calculate how much heat energy (in kJ) is absorbed when 3.40 g of calcium carbonate decomposes.

   6.04 kJ

   d. Calculate how much heat energy (in kJ) is gained when 5.65 moles of calcium oxide is produced.

   1005 kJ

   e. Calculate how many moles of calcium oxide are produced if 1,450 J of heat energy is consumed. Remember: $1 \text{ J} = 10^{-3} \text{ kJ}$

   0.00816 mol CaO

3. An LP gas tank in a home barbeque contains 13,200 g of propane (C_3H_8). When propane combusts with oxygen gas (O_2), it forms carbon dioxide (CO_2) and water vapor and releases 2044 kJ of heat energy.

   a. Complete and balance the chemical equation below. ***<u>Remember to include heat!</u>***

   $$\_\_\_\_\_\_ C_3H_8(g) + \_\_\_\_\_\_ O_2(g) \rightarrow \_\_\_\_\_\_ CO_2(g) + \_\_\_\_\_\_ H_2O(g)$$

   b. Use dimensional analysis to calculate how much heat energy (in kJ) is released when 3.0 moles of water is produced.

   -1500 kJ

   c. Use dimensional analysis to calculate how much heat energy (in kJ) is lost when all 13,200 g of propane are reacted with an excess of oxygen.

   -612,000 kJ

   d. Use dimensional analysis to calculate how many moles of carbon dioxide are produced if 684 kJ of heat energy are produced.

   1.00 mol CO_2

4. Nitrogen monoxide gas (NO) and liquid water can be reacted to form oxygen gas (O_2) and ammonia (NH_3). In the process, 1170 kJ of heat energy is gained.

   a. Complete and balance the chemical equation below. ***<u>Remember to include heat!</u>***

   $$\_\_\_\_\_\_ NO(g) + \_\_\_\_\_\_ H_2O(l) \rightarrow \_\_\_\_\_\_ NH_3(g) + \_\_\_\_\_\_ O_2(g)$$

   b. Use dimensional analysis to calculate how much heat energy (in kJ) is needed to produce 7.6 moles of ammonia.

   2200 kJ

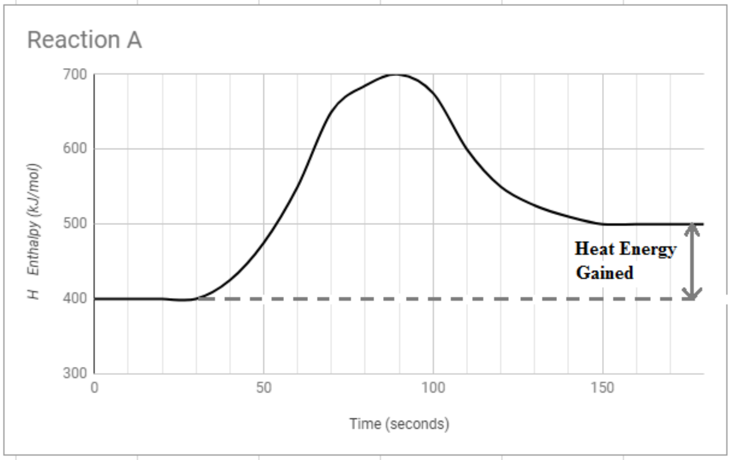
   c. Use dimensional analysis to calculate the amount of heat energy required (in kJ) to react 78.98 g of nitrogen monoxide gas.

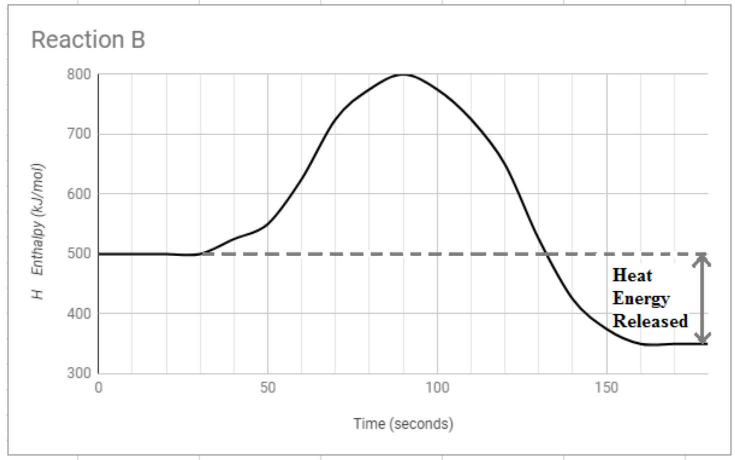
   770. kJ

   d. CHALLENGE Use dimensional analysis to calculate how many kilograms of water vapor are needed to absorb 15,980 J of heat energy. Remember: 1000 g = 1 kg and 1000 J = 1 kJ

   0.001476 kg H_2O

5. Consider the two enthalpy diagrams below and answer the following questions. *Pay attention to labels!*





Reaction A

a. This reaction is *exothermic* / *endothermic*

b. Calculate the ΔH. Use: $\Delta H = H_f - H_i$

c. Heat energy is a *product* / *reactant.*

d. The value of q would be *positive* / *negative*

e. The value of ΔT is *positive* / *negative.*

Reaction B

a. This reaction is *exothermic* / *endothermic*

b. Calculate the ΔH. Use: $\Delta H = H_f - H_i$

c. Heat energy is a *product* / *reactant.*

d. The value of q would be *positive* / *negative.*

e. The value of ΔT is *positive* / *negative.*

6. When solid magnesium (Mg) combines with oxygen gas (O_2), solid magnesium oxide (MgO) is formed and 1204 kJ of heat is released.

a) Complete and balance the thermochemical equation for this reaction. ***Remember to include heat!***

$$\_\_\_\_\_\_ Mg_{(s)} + \_\_\_\_\_\_ O_{2(g)} \rightarrow \_\_\_\_\_\_ MgO_{(s)}$$

b) How many kJ of heat energy are released when 5.25 moles of magnesium reacts with excess oxygen gas?

-3160 kJ

c) How many kJ of heat energy are released when 8.65 grams of MgO are produced.

-129 kJ

7. During an experiment, Eugene P. Piccadilly observed solid sodium hydroxide (the system) gave off energy when it was added to water (the surroundings). Where did this energy come from? Explain using the term "**chemical potential energy**".

8. During an experiment, Eugene P. Piccadilly observed solid ammonium nitrate (the system) absorb energy when it was added to water (the surroundings). Where did this energy come from? Explain using the term "**chemical potential energy**".

9. When burned, liquid ethanol (C_2H_5OH) reacts with oxygen (O_2) to produce carbon dioxide gas (CO_2) and water vapor (H_2O).

   a. Complete and balance the thermochemical equation for this reaction. ***Remember to include heat!***

   $$\_\_\_\_\_\_ \; C_2H_5OH_{(l)} + \_\_\_\_\_\_ \; O_{2(g)} \rightarrow \_\_\_\_\_\_ \; CO_{2(g)} + \_\_\_\_\_\_ \; H_2O_{(g)} \quad \Delta H = -1368 \text{ kJ}$$

   b) How much heat, in kJ, is released when 12.5g of ethanol burns?

   -371 kJ

   c) CHALLENGE: How many grams of ethanol would need to be burned in order to produce the same amount of heat as Godzilla's nuclear breath? (His breath releases 3.15×10^{14}J of heat)

   1.06×10^{10} g C_2H_5OH

Bond Enthalpy Practice Name: ______________________________

Chemistry Date: ________________ Hour: ________

Read (and annotate) this! Feel free to use the space at the bottom of the page to take additional notes from the EdPuzzle video (if assigned).

In a chemical reaction the reactant molecules are chemically converted into product molecules. The chemical bond(s) in the reactant molecule(s) are broken and new bond(s) are formed in the product(s). Energy must be absorbed to break a chemical bond (ΔH is positive) and energy is released (ΔH is negative) when bonds are formed. The enthalpy change (ΔH) for a chemical reaction can be calculated by looking at the difference in the sum of (Σ) the bond energies (BE) of the broken reactant bonds and the formed product bonds.

$$\Delta H = \sum BE_{broken} - \sum BE_{formeden}$$

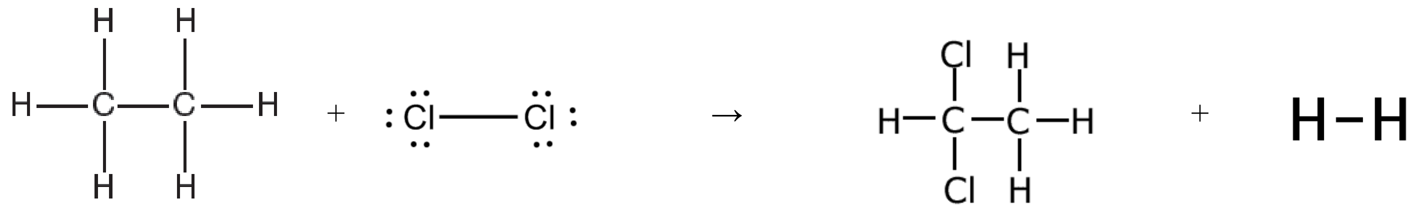
Bond Energies

Bond	Energy (kJ/mol)	Bond	Energy (kJ/mol)
H—H	432	N—N	160
C—H	411	N═O	631
N—H	386	N≡N	941
H—Cl	431	N—O	201
C—C	346	Cl—Cl	243
C—O	358	F—F	158
C—N	305	O—H	464
C—Cl	327	O—Cl	269
C═C	602	O—O	204
C═O	745	C—F	552
O═O	494	C—S	259

Reaction #1: Ethane and chlorine gas react.

$$C_2H_{6(g)} + Cl_{2(g)} \rightarrow C_2H_4Cl_{2(g)} + H_{2(g)}$$

The Lewis dot structures of the products and reactants are shown below.



1) a) The sum (Σ) of the bond energies broken is… b) The sum (Σ) of the bond energies formed is…

   c) The enthalpy change (ΔH) for the reaction is…

2) Use your answer from #1c to update the thermochemical equation found at the top of the section.

3) Is this reaction exothermic or endothermic? ___________________________________

Reaction #2: The combustion of hydrogen, H_2, to produce water: $2H_{2(g)} + O_{2(g)} \rightarrow 2H_2O_{(g)}$

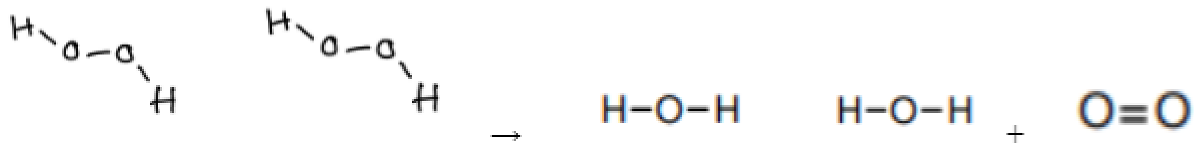
4) a) The sum (Σ) of the bond energies broken is… b) The sum (Σ) of the bond energies formed is…

   c) The enthalpy change (ΔH) for the reaction is…

5) Use your answer from #2c to update the thermochemical equation found at the top of the section.

6) Is this reaction exothermic or endothermic? ___________________________________

Reaction #3: The decomposition of hydrogen peroxide, H_2O_2. $2H_2O_{2(l)} \rightarrow 2H_2O_{(l)} + O_{2(g)}$



7) a) The sum (Σ) of the bond energies broken is… b) The sum (Σ) of the bond energies formed is…

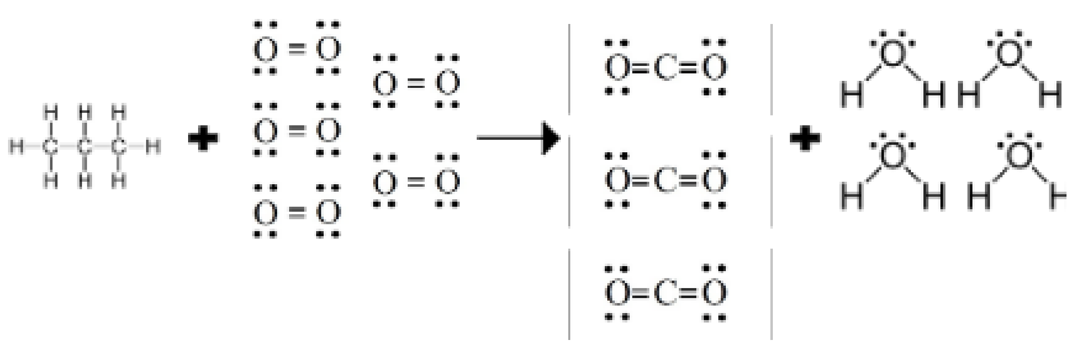
c) The enthalpy change (ΔH) for the reaction is…

8) Use your answer from #6c to update the thermochemical equation found at the top of the section.

9) Is this reaction exothermic or endothermic? ___________________________________

Reaction #4: The combustion of propane is shown in the balanced chemical equation:

$$C_3H_{8(g)} + 5O_{2(g)} \rightarrow 3CO_{2(g)} + 4H_2O_{(g)}$$



10) a) The sum (Σ) of the bond energies broken is… b) The sum (Σ) of the bond energies formed is…

c) The enthalpy change (ΔH) for the reaction is…

11) Use your answer from #16c to update the thermochemical equation found at the top of the section.

12) Is this reaction exothermic or endothermic? ___________________________________

Reaction #5: The following balanced thermochemical equation represents a hypothetical reaction between A_2 and B_2 producing the molecule AB. Use the given information to calculate the energy for the A__B bond.

$$A_2 + B_2 \rightarrow 2AB + 549kJ$$

The following bond energies are known:

Bond	Bond Energy (kJ/mol)
A__A	327
B__B	432
A__B	???

13) Calculate the A__B bond energy.

Answer the following questions by circling the correct answer that completes the sentence.

14) For an exothermic reaction the…

a) symbol for enthalpy change (ΔH) is always [*positive* / *negative*].

b) bond energies of the reactants is [*greater than* / *less than*] the bond energies of the products, while the enthalpy diagram shows the reactants [*higher* / *lower*] than the products.

15) For an endothermic reaction the…

a) symbol for enthalpy change (ΔH) is always [*positive* / *negative*].

b) bond energies of the reactants is [*greater than* / *less than*] the bond energies of the products, while the enthalpy diagram shows the reactants [*higher* / *lower*] than the products.

Heats of Formation Notes & Practice Name: ______________________________

Chemistry Date: __________________ Hour: _________

Complete the following questions using your notes on ***heats of formation****.*

1) Sometimes it is difficult to measure the enthalpy change for a chemical reaction (ΔH^0). What are the four reasons why? List them here…

a) ____

b) ____

c) ____

d) ____

2) Why do scientists study reactions at a "standard state"?

3) Define standard heat of formation (ΔH_f^0)...

4) Circle the substances that have a ΔH_f^0 of 0 kJ/mol…

Fe Br_2 $C_6H_{12}O_6$ Ne H_2 HCl $AgNO_3$ W NaOH $KMnO_4$ U $HClO_3$

5) Our notes state "For a reaction that occurs at standard conditions, you can calculate ΔH by using standard heats of formation ($\Delta H°_f$)." What is the mathematical formula we will use to calculate ΔH this way?

6) What unit is used to measure heat of formation?

The table below contains common substances and their Standard Heats of Formation (ΔH_f^0). Use this information to answer questions #7-10. Show your work in the space provided and write your final answer on the line.

$$\Delta H° = \Sigma\Delta H_f° \text{ (products)} - \Sigma\Delta H_f° \text{(reactants)}$$

Standard Heats of Formation (ΔH_f^0) for various substances				
Substance	ΔH_f^0 (kJ/mol)		Substance	ΔH_f^0 (kJ/mol)
$NO_{(g)}$	90.37		$H_2O_{2\,(l)}$	-187.80
$NO_{2\,(g)}$	33.85		$H_2O_{(l)}$	-285.80
$NH_{3\,(g)}$	-46.00		$H_2S_{(g)}$	-21.00
$HF_{(g)}$	-273.00		$SF_{6\,(g)}$	-1220.00

7) Calculate the standard heat of reaction (ΔH^0) for the following combination reaction:

$2\ NO_{(g)} + O_{2\,(g)} \rightarrow 2\ NO_{2\,(g)}$

ΔH^0 = ____________

-113.04 kJ/mol (exothermic)

8) Calculate the standard heat of reaction (ΔH^0) for the following decomposition reaction:

$2\ H_2O_{2\,(l)} \rightarrow O_{2\,(g)} + 2H_2O_{(l)}$

ΔH^0 = ____________

-196.0 kJ/mol (exothermic)

9) Calculate the standard heat of reaction (ΔH^0) for the following chemical reaction:

$4\ NH_{3\,(g)} + 5\ O_{2(g)} \rightarrow 4\ NO_{(g)} + 6\ H_2O_{(l)}$

ΔH^0 = ____________

-1169.32 kJ/mol (exothermic)

10) Calculate the standard heat of reaction (ΔH^0) for the following chemical reaction:

$H_2S_{(g)} + 4\ F_{2\,(g)} \rightarrow 2\ HF_{(g)} + SF_{6\,(g)}$

ΔH^0 = ____________

-1745 kJ/mol (exothermic)

The table below contains common substances and their Standard Heats of Formation (ΔH_f^0). Use this information to answer questions #11-14. Show your work in the space provided and write your final answer on the line.

$$\Delta H° = \Sigma\Delta H_f° \text{ (products)} - \Sigma\Delta H_f° \text{(reactants)}$$

Standard Heats of Formation (ΔH_f^0) for various substances				
Substance	ΔH_f^0 (kJ/mol)		Substance	ΔH_f^0 (kJ/mol)
$CH_{4(g)}$	-75		$NO_{2\ (g)}$	34
$NH_{3(g)}$	-46		$CCl_{4(l)}$	-128
$H_2O_{(l)}$	-286		$SO_{2(g)}$	-297
$SO_{3(g)}$	-396		----------	----------

11) Calculate the standard heat of reaction (ΔH^0) for the following combination reaction:

$CH_{4(g)} + 2Cl_{2(g)} \rightarrow CCl_{4(l)} + 2H_{2(g)}$

$\Delta H^0 =$ ____________

ΔH_0 = -53 kJ (exothermic)

12) Calculate the standard heat of reaction (ΔH^0) for the following decomposition reaction:

$N_{2(g)} + 2O_{2(g)} \rightarrow 2NO_{2(g)}$

$\Delta H^0 =$ ____________

ΔH_0 = 68 kJ (endothermic)

13) Calculate the standard heat of reaction (ΔH^0) for the following chemical reaction:

$4NH_{3(g)} + 7O_{2(g)} \rightarrow 4NO_{2\ (g)} + 6H_2O_{(l)}$

$\Delta H^0 =$ ____________

ΔH_0 = -1396 kJ (exothermic)

14) Calculate the standard heat of reaction (ΔH^0) for the following chemical reaction:

$2SO_{2(g)} + O_{2(g)} \rightarrow 2SO_{3(g)}$

$\Delta H^0 =$ ____________

ΔH_0 = -198 kJ (exothermic)

Hess's Law Notes & Practice

Name: ________________________________

How do we use Hess's Law?

To use Hess's Law, two or more __________________ __________________ are added together to give a __________________ __________________ . The __________________ of __________________ are also added together to give a final __________________ of __________________ .

Steps to Use Hess's Law

1. Determine the reactants and products in the UNKNOWN chemical equation.
2. Locate the reactants and products in the KNOWN chemical equations.
3. Determine if any KNOWN equation needs to be flipped. (*If you flip the equation, flip the sign of* ΔH)
4. Determine if any KNOWN equation need to be multiplied/divided by anything.*(If you X or ÷ , apply it to* ΔH*)*
5. Combine the KNOWN equations into 1 equation and cross out substances that are the same on each side.
6. Add the reaction enthalpies together.

Perform the following calculations using Hess's Law. Show your work & write your final answer on the line provided.

1) The enthalpy changes for the following reactions are known:

(1) $N_{2(g)} + O_{2(g)} \rightarrow 2NO_{(g)}$ $\Delta H = 180$ kJ

(2) $2NO_{(g)} + O_{2(g)} \rightarrow 2NO_{2(g)}$ $\Delta H = -112$ kJ

Use Hess's Law to calculate ΔH for the following reaction:

$N_{2(g)} + 2O_{2(g)} \rightarrow 2NO_{2(g)}$ $\Delta H =$ ________

$\Delta H = +68$ kJ

What changes do we need to make to the equations?

2) The enthalpy changes for the following reactions are known:

(1) $P_{4(s)} + 3O_{2(g)} \rightarrow P_4O_{6(s)}$ $\Delta H = -1640.1$ kJ

(2) $P_{4(s)} + 5O_{2(g)} \rightarrow P_4O_{10(s)}$ $\Delta H = -2940.1$ kJ

Use Hess's Law to calculate ΔH for the following reaction:

$P_4O_{6(s)} + 2O_{2(g)} \rightarrow P_4O_{10(s)}$ $\Delta H =$ ________

$\Delta H = -1300.0$ kJ

What changes do we need to make to the equations?

3) The enthalpy changes for the following reactions are known:

(1) $4NH_{3(g)} + 3O_{2(g)} \rightarrow 2N_{2(g)} + 6H_2O_{(l)}$ $\Delta H = -0.00153$ kJ

(2) $4NH_{3(g)} + 5O_{2(g)} \rightarrow 4NO_{(g)} + 6H_2O_{(l)}$ $\Delta H = -0.00117$ kJ

Use Hess's Law to calculate ΔH for the following reaction:

$N_{2(g)} + O_{2(g)} \rightarrow 2NO_{(g)}$ $\Delta H =$ ________

What changes do we need to make to the equations?

ΔH = 1.80x10-4 kJ

4) The enthalpy changes for the following reactions are known:

(1) $Ca_{(s)} + 2C_{(s)} \rightarrow CaC_{2(s)}$ $\Delta H = -62.8$ kJ

(2) $CO_{2(g)} \rightarrow C_{(s)} + O_{2(g)}$ $\Delta H = 393.5$ kJ

(3) $2CaCO_{3(s)} + 2CO_{2(g)} \rightarrow 2CaC_{2(s)} + 5O_{2(g)}$ $\Delta H = 3076$ kJ

Use Hess's Law to calculate ΔH for the following reaction:

$2Ca_{(s)} + 2C_{(s)} + 3O_{2(g)} \rightarrow 2CaCO_3$ $\Delta H =$ ________

What changes do we need to make to the equations?

ΔH = -2414.6 kJ

5) The enthalpy changes for the following reactions are known:

(1) $2CO_{(g)} + O_{2((g)} \rightarrow 2CO_{2(g)}$ $\Delta H = -566.0\ kJ$

(2) $N_{2(g)} + O_{2(g)} \rightarrow 2NO_{(g)}$ $\Delta H = -180.6\ kJ$

Use Hess's Law to calculate ΔH for the following reaction:

$2CO_{(g)} + 2NO_{(g)} \rightarrow 2CO_{2(g)} + N_{2(g)}$ $\Delta H =$ ________

ΔH = -385.4 kJ

What changes do we need to make to the equations?

6) The enthalpy changes for the following reactions are known:

(1) $4Al_{(s)} + 3O_{2(g)} \rightarrow 2Al_2O_{3(s)}$ $\Delta H = -3352\ kJ$

(2) $Mn_{(s)} + O_{2(g)} \rightarrow MnO_{2(s)}$ $\Delta H = -521\ kJ$

Use Hess's Law to calculate ΔH for the following reaction:

$4Al_{(s)} + 3MnO_{2(g)} \rightarrow 2Al_2O_{3(s)} + 3Mn_{(s)}$ $\Delta H =$ ________

ΔH = -1789 kJ

What changes do we need to make to the equations?

7) The enthalpy changes for the following reactions are known:

(1) $A \rightarrow 2B$ $\Delta H = 30\ kJ$

(2) $B \rightarrow C$ $\Delta H = -40\ kJ$

(3) $2C \rightarrow D$ $\Delta H = -15\ kJ$

Use Hess's Law to calculate ΔH for the following reaction:

$D + A \rightarrow 4C$ $\Delta H =$ ________

ΔH = -35 kJ

What changes do we need to make to the equations?

Hess's Law Extra Practice

Name: ______________________________

Chemistry

Date: ________________ Hour: ________

Perform the following calculations using Hess's Law. Show your work and write your final answer on the line provided.

1) The enthalpy changes for the following reactions are known:

(1) $2CO_{(g)} + O_{2((g)} \rightarrow 2CO_{2(g)}$ $\Delta H = -566.0$ kJ

(2) $N_{2(g)} + O_{2(g)} \rightarrow 2NO_{(g)}$ $\Delta H = -180.6$ kJ

Use Hess's Law to calculate ΔH for the following reaction:

$2CO_{(g)} + 2NO_{(g)} \rightarrow 2CO_{2(g)} + N_{2(g)}$ $\Delta H =$ ________

What changes do we need to make to the equations?

2) The enthalpy changes for the following reactions are known:

(1) $4Al_{(s)} + 3O_{2(g)} \rightarrow 2Al_2O_{3(s)}$ $\Delta H = -3352$ kJ

(2) $Mn_{(s)} + O_{2(g)} \rightarrow MnO_{2(s)}$ $\Delta H = -521$ kJ

Use Hess's Law to calculate ΔH for the following reaction:

$4Al_{(s)} + 3MnO_{2(g)} \rightarrow 2Al_2O_{3(s)} + 3Mn_{(s)}$ $\Delta H =$ ________

What changes do we need to make to the equations?

3) The enthalpy changes for the following reactions are known:

(1) $A \rightarrow 2B$ $\Delta H = 30$ kJ

(2) $B \rightarrow C$ $\Delta H = -40$ kJ

(3) $2C \rightarrow D$ $\Delta H = -15$ kJ

Use Hess's Law to calculate ΔH for the following reaction:

$D + A \rightarrow 4C$ $\Delta H =$ ________

What changes do we need to make to the equations?

4) The enthalpy changes for the following reactions are known:

(1) $BCl_3(g) + 3\ H_2O(l) \rightarrow H_3BO_3(g) + 3\ HCl(g)$ $\Delta H = -112.5$ kJ

(2) $B_2H_6(g) + 6\ H_2O(l) \rightarrow 2\ H_3BO_3(s) + 6\ H_2(g)$ $\Delta H = -493.4$ kJ

(3) $1/2\ H_2(g) + 1/2Cl_2(g) \rightarrow HCl(g)$ $\Delta H = -92.3$ kJ

Use Hess's Law to calculate ΔH for the following reaction:

$B_2H_6(g) + 6\ Cl_2(g) \rightarrow 2\ BCl_3(g) + 6\ HCl(g)$

What changes do we need to make to the equations?

5) The enthalpy changes for the following reactions are known:

(1) $OF_2(g) + H_2O(l) \rightarrow O_2(g) + 2\ HF(g)$ $\Delta H = -276.6$ kJ

(2) $SF_4(g) + 2\ H_2O(l) \rightarrow 4\ HF(g) + SO_2(g)$ $\Delta H = -827.5$ kJ

(3) $S(s) + O_2(g) \rightarrow SO_2(g)$ $\Delta H = -296.9$ kJ

Use Hess's Law to calculate ΔH for the following reaction:

$2\ OF_2(g) + 2\ S(s) \rightarrow SO_2(g) + SF_4(g)$

What changes do we need to make to the equations?

6) The enthalpy changes for the following reactions are known:

(1) $N_2H_4(l) + O_2(g) \rightarrow N_2(g) + 2\ H_2O(l)$ $\Delta H^o/kJ = -622.3$ kJ

(2) $H_2(g) + 1/2\ O_2(g) \rightarrow H_2O(l)$ $\Delta H = -285.8$ kJ

(3) $H_2(g) + O_2(g) \rightarrow H_2O_2(l)$ $\Delta H = -187.8$ kJ

Use Hess's Law to calculate ΔH for the following reaction:

$N_2H_4(l) + 2\ H_2O_2(g)\ N_2(g) + 4\ H_2O(l)$

What changes do we need to make to the equations?

~~7) The enthalpy changes for the following reactions are known:~~

~~(1) 1/4 $P_4(s)$ + 3/2 → $Cl_2(g)$ $PCl_3(g)$ ΔH°/kJ = -306.4~~

~~(2) $P_4(s) + 5\ O_2(g) \rightarrow P_4O_{10}(g)$ ΔH = -2967.3 kJ~~

~~(3) $PCl_3(g) + Cl_2(g) \rightarrow PCl_5(g)$ ΔH = -84.2 kJ~~

~~(4) $PCl_3(g) + 1/2\ O_2(g) \rightarrow Cl_3PO(g)$ ΔH = -285.7 kJ~~

~~Use Hess's Law to calculate ΔH for the following reaction:~~

~~$P_4O_{10}(g) + 6\ PCl_5(g) \rightarrow 10\ Cl_3PO(g)$~~

This problem is incorrectly formatted. Do not attempt it.

What changes do we need to make to the equations?

~~8) The enthalpy changes for the following reactions are known:~~ ~~$SOCl_2(l) + H_2O(l) \rightarrow SO_2(g) + 2\ HCl(g)$ ΔH°/kJ = +10.3~~

~~(1) $PCl_3(l) + 1/2\ O_2(g) \rightarrow POCl_3(l)$ ΔH = -325.7 kJ~~

~~(2) $P(s) + 3/2\ Cl_2(g) \rightarrow PCl_3(l)$ ΔH = -306.7 kJ~~

~~(3) $4\ HCl(g) + O_2(g) \rightarrow 2\ Cl_2(g) + 2\ H_2O(l)$ ΔH = -202.6 kJ~~

~~Use Hess's Law to calculate ΔH for the following reaction:~~

~~$2\ SO_2(g) + 2\ P(s) + 5\ Cl_2(g) \rightarrow 2\ SOCl_2(l) + 2\ POCl_3(l)$~~

This problem is incorrectly formatted. Do not attempt it.

What changes do we need to make to the equations?

9) The enthalpy changes for the following reactions are known:

(1) $3\ C(s) + 4\ H_2(g) \rightarrow C_3H_8(g)$ ΔH = -103.8 kJ

(2) $C(s) + O_2(g) \rightarrow CO_2(g)$ ΔH = -393.5 kJ

(3) $H_2(g) + 1/2\ O_2(g) \rightarrow H_2O(g)$ ΔH = -241.8 kJ

Use Hess's Law to calculate ΔH for the following reaction:

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

What changes do we need to make to the equations?

10) The enthalpy changes for the following reactions are known:

(1) $2\ H_2(g) + O_2(g) \rightarrow 2\ H_2O(l)$ $\Delta H^o/kJ = -571.6$

(2) $N_2O_5(g) + H_2O(l) \rightarrow 2\ HNO_3(l)$ $\Delta H = -73.7$ kJ

(3) $N_2(g) + 3\ O_2(g) + H_2(g) \rightarrow 2\ HNO_3(l)$ $\Delta H = -348.2$ kJ

Use Hess's Law to calculate ΔH for the following reaction:

$2\ N_2(g) + 5\ O_2(g) \rightarrow 2\ N_2O_5(g)$

What changes do we need to make to the equations?

11) The enthalpy changes for the following reactions are known:

(1) $C(s) + O_2(g) \rightarrow CO_2(g)$ $\Delta H = -393.5$ kJ

(2) $H_2(g) + 1/2\ O_2(g) \rightarrow H_2O(l)$ $\Delta H = -285.8$ kJ

(3) $CO_2(g) + 2\ H_2O(l) \rightarrow CH_4(g) + 2\ O_2(g)$ $\Delta H = +890.3$ kJ

Use Hess's Law to calculate ΔH for the following reaction:

$C(s) + 2\ H_2(g) \rightarrow CH_4(g)$

What changes do we need to make to the equations?

Phase Changes Notes & Practice Name: ___________________________

Chemistry Date: _______________ Hour: ________

Kinetic Molecular Theory -- Review

➔ Matter is made up of particles that are in **constant random motion**
➔ Motion of particles = **kinetic energy**
➔ The average kinetic energy of a substance is its **temperature**
➔ **Temperature** determines state of matter (s, l, g)

States of Matter -- Defined

State of matter	Shape	Volume	Spacing of particles	Attraction between particles	Relative motion of particles
Solid	Definite	Definite	Very close	Strong	
Liquid	Indefinite	Definite	Moderately close	Moderate	
Gas	Indefinite	Indefinite	Random Far apart	None	

Phase Changes -- Defined

➔ Phase changes are ____________ ____________. This means they are ____________.
➔ During a phase change, a substance changes state of matter (solid, liquid, gas)
➔ The ____________ of the substance does not change. But, the ____________ does!
- ◆ Phase changes absorb or release energy just like chemical reactions.
- ◆ The change in energy associated with a physical or chemical change is called **enthalpy** and is represented by the variable ____________.
- ◆ When energy is ____________, the particles increase in kinetic energy causing them to warm up. These types of phase changes have a ___ΔH.
- ◆ When energy is ____________, the particles decrease in kinetic energy causing them to cool down. These types of phase changes have a ___ΔH.

$$S \rightleftarrows L \rightleftarrows G$$

Phase Changes -- Breakdown

Melting

- A substance goes from ____________ to ____________ .
- ____________ energy (___ΔH).
- Particles increase in kinetic energy and break from their fixed positions.
- ____________ ____________ -- the temperature at which solid changes to liquid.
- Both states of matter (S and L) are present until all of the solid has melted.

Vaporization (evaporation & boiling)

- A substance goes from ____________ to ____________ .
- ____________ energy (___ΔH).
- Particles increase in kinetic energy and break from their fixed positions.
- ____________ ____________ -- the temperature and pressure at which liquid changes to gas.
- Both states of matter (L and G) are present until all of the solid has vaporized.

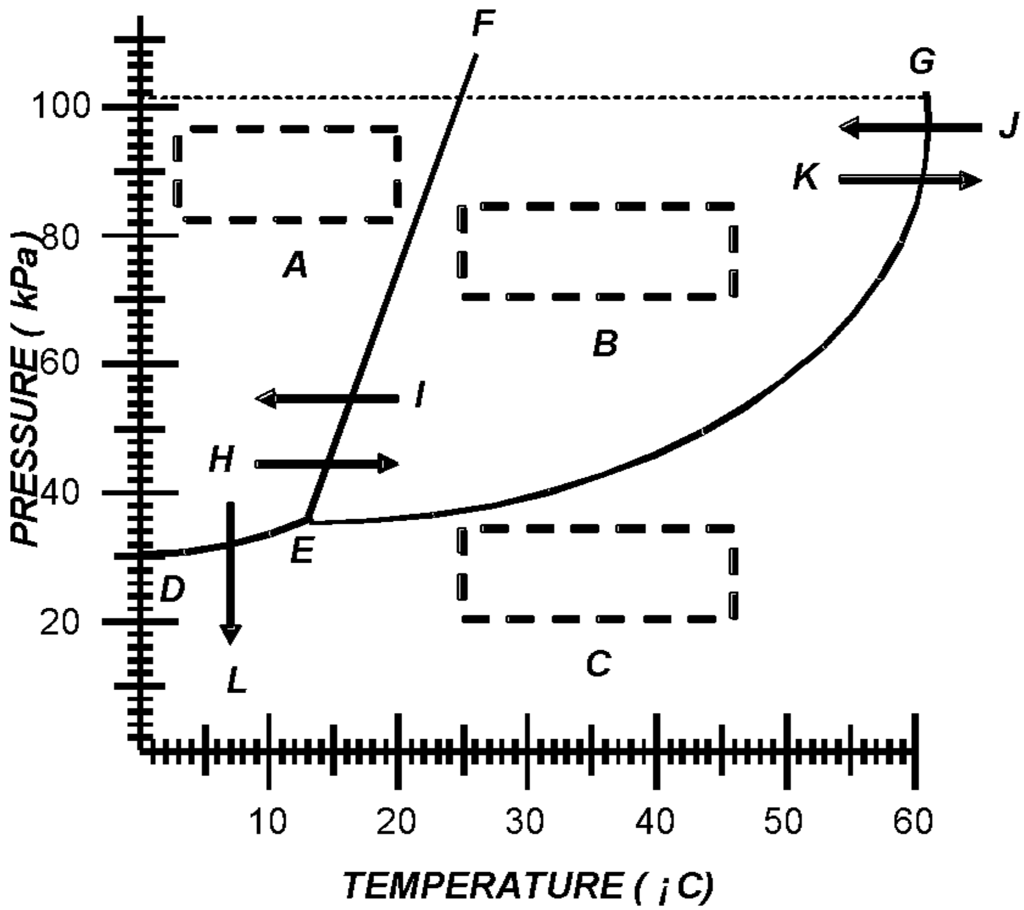
Freezing (solidification)

- A substance goes from ____________ to ____________ .
- ____________ energy (___ΔH).
- Particles decrease in kinetic energy and attraction is greater than motion.
- ____________ ____________ -- the temperature at which liquid changes to solid. Freezing and melting occur at the ____________ ____________ !
- Both states of matter (S and L) are present until all of the liquid freezes.

Condensation

- A substance goes from ____________ to ____________ .
- ____________ energy (___ΔH).
- Particles decrease in kinetic energy and attraction is greater than motion.
- ____________ ____________ -- the temperature at which gas changes to liquid. Vaporization and condensation occur at the ____________ ____________ !
- Both states of matter (L and G) are present until all of the gas condenses.

Directions: Use the phase diagram below to complete the following questions.



1. Identify the following:
    a. Normal (1 atm = 760 mm Hg = 101.3 kPa) boiling point ____________________________
    b. Normal melting point ____________________________

2. Estimate the following:
    a. Boiling point when the pressure is 60 kPa _______________
    b. Melting point when the pressure is 80 kPa _______________
    c. Sublimation point when the pressure is 32 kPa ____________

3. Identify the phase (solid, liquid, gas) at…
    a. 80 kPa and 5°C _______________
    b. 60 kPa and 40°C _______________
    c. 20 kPa and 50°C _______________

4. ______ At 50 kPa, increasing the temperature from 10° C to 20° C while keeping the pressure constant results in ___.
   a. vaporization b. melting c. no change d. condensation

5. ______ At 10° C, decreasing the pressure from 100 kPa to 10 kPa while keeping the temperature constant results in ____.
   a. sublimation b. melting c. boiling d. freezing

6. ______ At 50° C, increasing the pressure from 20 kPa to 80 kPa while keeping the temperature constant results in ____.
   a. condensation b. melting c. boiling d. freezing

CHALLENGE! Consider the following normal melting point and normal boiling point data below.

Substance	Normal melting point (°C)	Normal boiling point (°C)
Butanol	-89.0	117.7
Ethane	-182.8	-89.0
Naphthalene	80.26	218
Salicylic acid	158.6	211

7. Identify any substances that are solids at room temperature (25°C).

8. Identify any substances that are liquids at room temperature (25°C).

9. Identify any substances that are gases at room temperature (25°C).

10. Which substance has the largest interparticle attractions? The smallest?

Enthalpies of Phase Changes Notes & Practice

Name: ________________________________

Chemistry

Date: __________________ Hour: _________

Classifying Enthalpy of Phase Changes

Molar heat of fusion

- Variable: ____________ Unit: ____________
- The heat energy ____________ by one mole of a substance in ____________ from a solid to a liquid.
- ___ΔH
- Calculate: ________________________
- Occurs at the ____________ ____________ . **No** temperature change.

Molar heat of solidification

- Variable: ____________ Unit: ____________
- The heat energy ____________ by one mole of a substance in ____________ from a liquid to a solid.
- ___ΔH
- Calculate: ________________________
- Occurs at the ____________ ____________ . **No** temperature change.

Heat absorbed by a melting solid ***__is equal__* to heat lost when a liquid solidifies** This means ___________

Molar heat of vaporization

- Variable: ____________ Unit: ____________
- The heat energy ____________ by one mole of a substance in ____________ from a liquid to a gas.
- ___ΔH
- Calculate: ________________________
- Occurs at the ____________ ____________ . **No** temperature change.

Molar heat of condensation

- Variable: ____________ Unit: ____________
- The heat energy ____________ by one mole of a substance in ____________ from a gas to a liquid.
- ___ΔH
- Calculate: ________________________
- Occurs at the ____________ ____________ . **No** temperature change.

Heat absorbed by a boiling liquid ***__is equal__* to heat lost when a gas condenses** This means ___________

There are other "molar heats". You just did a lab on the molar heat of combustion! Molar heat of solidification is another example. You will only be tested on the molar heats of the phase changes.

Use the information in the table below to calculate the enthalpy of the phase change described in each question.. Show your work and round your answer according to the rules of significant figures.

Substance	**Heat of Fusion (kJ/mol)**	**Heat of Vaporization (kJ/mol)**
Water (H_2O)	6.01	40.7
Ethanol (C_2H_5OH)	4.60	43.5
Gold (Au)	12.6	342
Oxygen (O_2)	0.44	6.82

1 mol X = molar mass of X **1000 J = 1 kJ** **$q = mol\Delta H_{phasechange}$**

1) How much energy, in kJ, would be absorbed in order to completely boil 100.0 mol of water?

2) How much energy, in kJ, is required to completely melt a 14.9 g piece of gold metal?

3) How much energy, in J, is required to turn 162 mol of oxygen gas into liquid oxygen?

4) How much heat energy, in J, would be used to freeze 84.4 g of ethanol?

5) A goldsmith uses 46,000 J of heat to completely melt a solid piece of gold metal. What was the mass of the sample of gold metal?

Heating Curves Notes

Name ________________________

Chemistry

Date ______________ Hour _____

Phase Changes

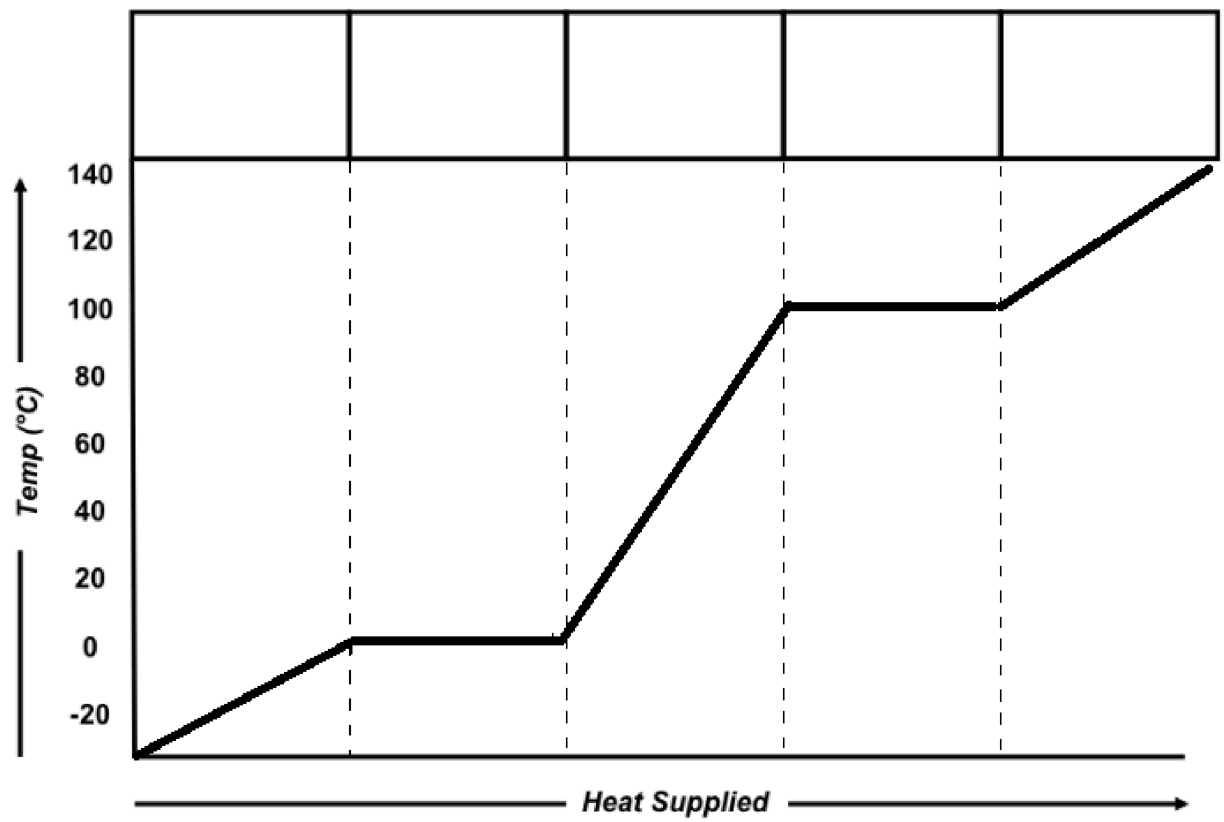
- Phase changes are ________________________.
  - This means that there is a change of _____________________, but the ___________________ of the substance does not change.
- __________________ changes during a phase change
  - Endothermic → Energy _____________ = ________ kinetic energy.
  - Exothermic → Energy _______________ = ________ kinetic energy.
- But ____________________ does NOT change during a phase change!

Name of Phase Change	States of Matter	Endo or Exo?	Name of Enthalpy	Variable	Formula used
Melting			Heat of		
Vaporization			Heat of Vaporization		
Freezing			Heat of	$\Delta H_{solid.}$	
Condensation			Heat of		$q = \Delta H_{cond.}$

Formulas for the Enthalpy of Phase Changes:

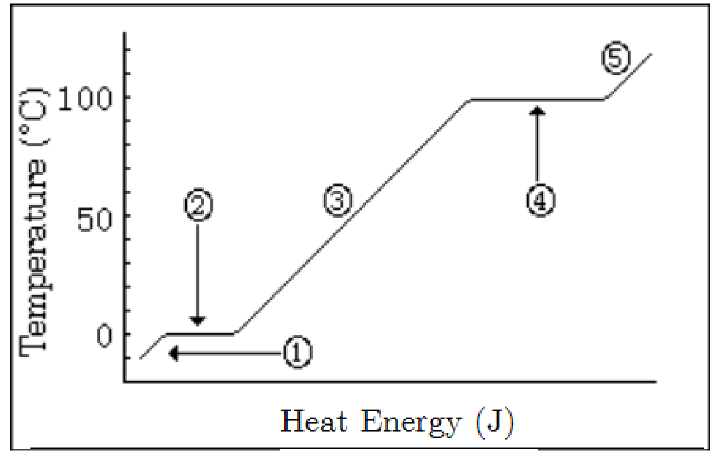
Steps to calculating the heat content (enthalpy) of a phase change:

1. Plot your _________________ and _________________ points on the heating curve.
2. Determine the _______________________ you need to use for each segment of the curve.
3. Plug in the ______________ _____________ into the formulas.
4. Add all __________ ______________(___) together (make sure your units match: J and kJ)



Practice Problems

Use the heating curve to the right for the following questions.



1) If we were to heat up 45.0 g of water from 20.0℃ to 80.0℃
   a) What is the boiling point of this curve? What is the freezing point?
   b) What segment(s) would we pass through and in what direction?
   c) Calculate the heat energy released/absorbed due to this change.

2) If 45.0 g of liquid water was cooled from 100.℃ to 50.0℃.
   a) What segment(s) would we pass through and in what direction?
   b) Calculate the heat energy released/absorbed due to this change. this

3) If 45.0 g of ice at 0.0℃ was melted and warmed to its boiling point.
   a) What segment(s) would we pass through and in what direction?
   b) Calculate the heat energy released/absorbed in kilojoules due to this change.

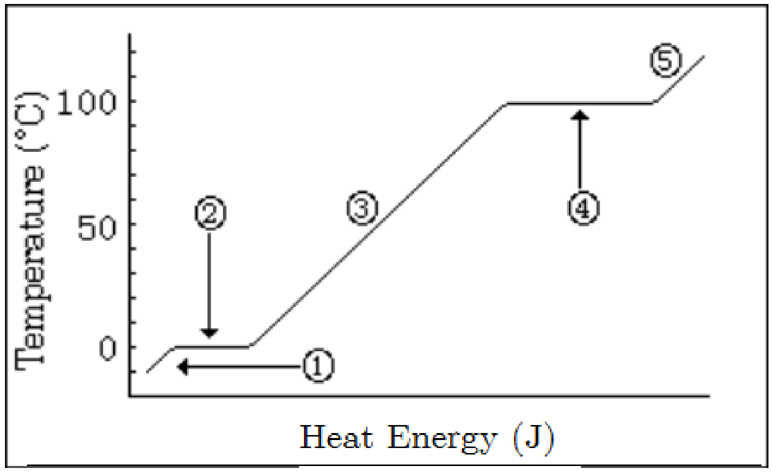
4) If 45.0 g of water vapor is cooled from 102°C to -6.0°C.
   a) What segment(s) would we pass through and in what direction?
   b) Calculate the heat energy released/absorbed in joules due to

      change.

Heating Curves Practice

Name: ______________________________

Date: __________________ Hour: _________



The following is a heating curve graph representing a sample of water that is initially ice at -10°C and is absorbing a near constant rate of heat transfer.

1) At segment (1), describe what is happening to the kinetic energy of the particles as they absorb energy from the heat source.

____

2) What state(s) of matter is/are present during segment (2)? _______________________________

3) What phase change, if any, is taking place at segment (2)? _______________________________

4) What formula would you use to calculate heat at segment (3)? ____________________________

5) What phase change, if any, is taking place at segment (4)? _______________________________

6) What formula would you use to calculate heat at segment (4)? ____________________________

7) What is the melting point of this substance? ____

8) What is the freezing point of this substance? _______________________________________

Use the information in the below to calculate the following phase change energy problems. A complete answer will show all work, proper units, and be rounded according to the rules of significant figures.

1 mol X = molar mass of X **1000 J = 1 kJ** **$q = mol\Delta H_{phasechange}$** **$q=mC\Delta T$**

Substance	**ΔH_{fus} Heat of Fusion (kJ/mol)**	**ΔH_{vap} Heat of Vaporization (kJ/mol)**	***C* Specific Heat (J/g°C)**
Water	6.01	40.7	4.184
Gold	12.6	342	0.131

9) Use the table above to determine how much energy, in J, is needed to change 125.0 g of water at 20.00°C to 80.00°C.

10) Use the table above to determine how much heat energy, in J, is required to completely melt a 35.56 g brick of gold. How many kJ of heat energy is this equal to?

Naphthalene, which is used in mothballs, has a melting point of 80.0°C and a boiling point of 217°C. Draw the heating curve graph for naphthalene on the blank graph provided below:

Information about naphthalene:

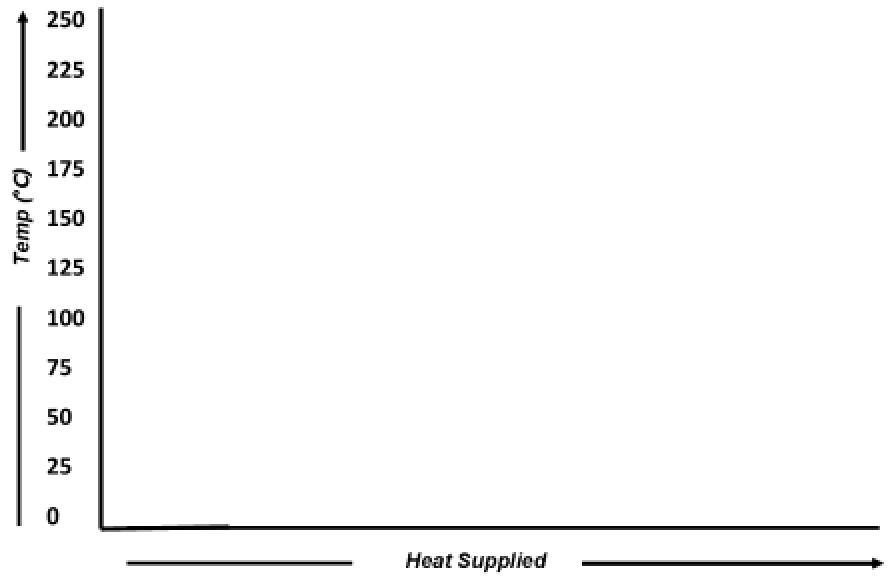
Molar Mass = 128.17 g/mol

$C_{naphthalene}$ = 1.18 J/g°C

ΔH_{fus} = 0.162 kJ/mol

ΔH_{vap} = 0.316 kJ/mol

Recall: 1000 J = 1kJ



11) How much heat energy, in kJ, would be released if 108.67 g of liquid naphthalene was solidified into mothballs?

12) How much heat energy, in kJ, would be absorbed to vaporize 80.0 g of naphthalene?

13) Using the heating curve graph above, determine how much heat energy, in kJ, must be added to 40.0g of naphthalene at 45.0°C to raise its temperature to 200.°C? *Show your work on a separate piece of paper.*

14) Using the heating curve graph above, determine how much heat energy, in kJ, would be lost from 1000.0 g of naphthalene at 250.°C to cool it down to 50.0°C. *Show your work on a separate piece of paper.*

15) Using the heating curve graph above, determine how much heat energy, in kJ, must be expelled from 20.0 g of naphthalene at 250.0°C to lower its temperature to 0.0°C. *Show your work on a separate piece of paper.*

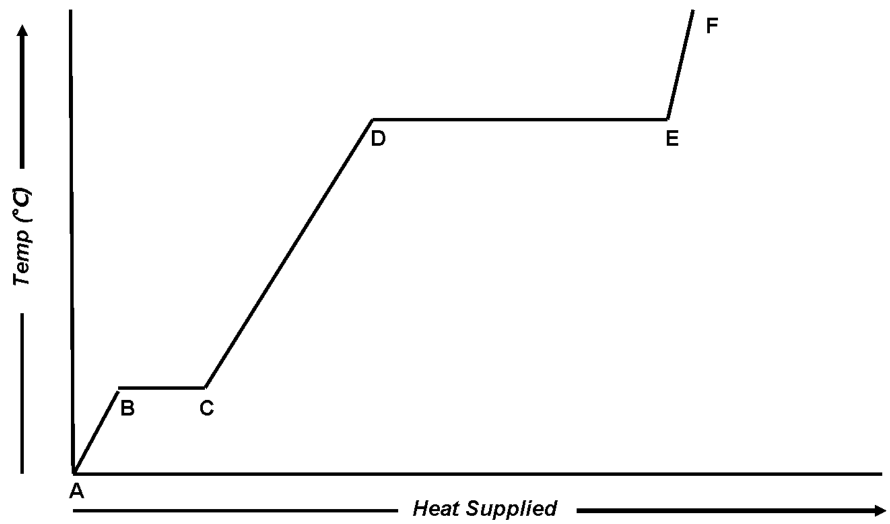
Heating Curve EXTRA Practice Name: ________________________________

Chemistry Date: __________________ Hour: _________

The organic compound acetone is a principal ingredient in most nail polish removers. Here are some of acetone's physical properties:

- molecular formula of C_3H_6O
- freezing point of -95.2 °C
- ΔH_{fus} +5.72 kJ/mol
- $C_{acetone}$ = 1.00 J/g×°C
- boiling point of 56.4 °C
- ΔH_{vap} is + 29.1 kJ/mol

Using the information above, answer the following questions regarding acetone's heating curve graph.



1) What temperature is acetone at when it is at location **B**?

____

2) What temperature is acetone at when it is at location **D**?

____

3) The temperature of acetone is not changing from location **B** to **C**, but heat is still being added. Explain.

4) What states(s) of matter exist between **A** and **B**? ____________________________________

5) What states(s) of matter exist between **D** and **E**? ____________________________________

6) When going from point B to C, what is the name/symbol of the enthalpy? ____________________

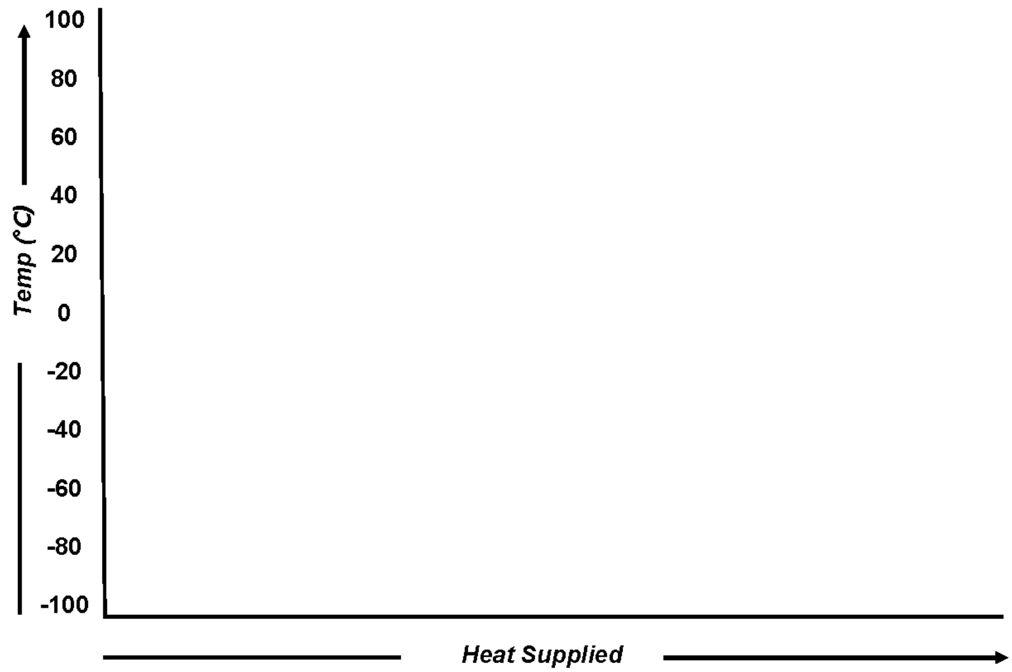
7) When going from point C to B, what is the name/symbol of the enthalpy? ____________________

8) When going from point D to E, what is the name/symbol of the enthalpy? ____________________

9) When going from point E to D, what is the name/symbol of the enthalpy? ____________________

10) Suppose you had 10.0 g of both liquid water and liquid acetone. Which would be easier to vaporize? The ΔH_{vap} for H_2O is 40.7 kJ/mol. Explain your reasoning.

11) Redraw acetone's heating curve graph by accurately representing its freezing and boiling points.



1 mol X = molar mass of X **1000 J = 1 kJ** $\mathbf{q = mol\Delta H_{phasechange}}$ $\mathbf{q=mC\Delta T}$

12) Using the heating curve graph from #11, determine how much heat energy, in kJ, must be added to 20.0g of acetone at -100.0°C to raise its temperature to 100.0°C. Recall that 1 kJ = 1000 J. A complete answer will show all work, proper units, and be rounded according to the rules of significant figures.

Unit 09 Test Review -- Thermochemistry Name: ________________________________

Chemistry Date: __________________ Hour: _________

Matching -- *Match the correct vocabulary term to each numbered statement. Write the letter of the correct term on the line provided.*

1) ____ A process that loses heat to the surroundings.
2) ____ A chemical change in which heat is absorbed from the surroundings
3) ____ A device used to measure the amount of heat absorbed or released during a chemical or physical change.
4) ____ The type of energy that is transferred due to a difference in temperature
5) ____ The unit we use to measure energy
6) ____ The heat absorbed by one mole of a substance in melting from a solid
7) ____ If two or more thermochemical equations are added to give a final equation, their enthalpies can be added to determine the final heat of the reaction.
8) ____ The amount of heat energy required to raise the temperature of one gram of a substance by 1°C.
9) ____ The heat released by one mole of a substance during condensation.
10) ____ The concept that explains that the heat lost by the system must equal the heat absorbed by the surroundings.

A) Heat
B) Endothermic reaction
C) Joule
D) Exothermic reaction
E) Molar heat of fusion
F) Calorimeter
G) Hess's Law
H) Specific heat
I) Molar heat of condensation
J) Law of Conservation Of Energy

Multiple Choice -- *Read the statement and select or write in the best response.*

11) ______125 J of heat is added to two different metals, metal A and metal B. Both metals are of equal mass and were initially at the same temperature. Metal B's final temperature was greater than metal A's final temperature. As a result of this observation ___.
   a) metal A's specific heat is larger than metal B's
   b) metal B's specific heat is larger than metal A's
   c) the metals have the same specific heat

12) ______A piece of Metal A (C = 1.07 J/g°C) and Metal B (C = 0.76 J/g°C) were heated from room temperature to 100°C. Each metal is then placed into a separate beaker containing 100g of water at room temperature, 25°C. Which statement is true?
   a) The two beakers will have the same maximum temperature.
   b) The beaker containing metal A will show the largest maximum temperature.
   c) The beaker containing metal B will show the largest maximum temperature.
   d) More information is needed to answer this question.

13) ______ The temperature in Lake Michigan won't reach a reasonable swimming temperature until about mid-summer. The reason for this observation is ___.
   a) the small specific heat of water
   b) the large specific heat of water
   c) the large mass of water
   d) both B & C

14) In an <u>exothermic</u> process… (circle the correct response in each statement below)

a) heat is *[gained / released]* by the system
b) q is *[positive / negative]*
c) ΔT is *[positive / negative]*
d) ΔH is *[positive / negative]*
e) Heat is a *[product / reactant]*
f) A flask containing this type of reaction would feel *[cold / warm]* to the touch

15) In an <u>endothermic</u> process… (circle the correct response in each statement below)

a) heat is *[gained / released]* by the system
b) q is *[positive / negative]*
c) ΔT is *[positive / negative]*
d) ΔH is *[positive / negative]*
e) Heat is a *[product / reactant]*
f) A flask containing this type of reaction would feel *[cold / warm]* to the touch

16) The enthalpy changes for the following reactions are known…

(1) $2CO_2 \rightarrow 2C + 2O_2$ $\Delta H = 787$ kJ
(2) $2CaC_2 + 5O_2 \rightarrow 2CaCO_3 + 2CO_2$ $\Delta H = -3076$ kJ

Apply Hess's Law to determine the number of O_2 molecules that would results in the final equation.

a) All of the O_2 molecules would cancel out.
b) 7 molecules would result on the product side
c) 3 molecules would result on the reactant side
d) 3 molecules would result on the product side

Calculations -- *Complete the following calculations by showing your work, rounding your answer according to the rules of significant figures and by including proper units.*

The following information will be provided for you on your test… It is up to you to know WHEN and HOW to use it!

1 mol X = molar mass of X **1000 J = 1 kJ**

$$q = mC\Delta T \qquad q_{system} + q_{surroundings} = 0$$

$$\Delta T = T_f - T_i \qquad C_{water} = 4.184\ J/g°C$$

$$\Delta H° = \Sigma \text{Bond Energy (broken)} - \Sigma \text{Bond Energy (formed)}$$

$$\Delta H° = \Sigma \Delta H_f°_{(products)} - \Sigma \Delta Hf°_{(reactants)} \qquad q = mol\Delta H_{phasechange}$$

17) The metabolism of the sugar glucose, $C_6H_{12}O_6$, is a major energy source in the body. The metabolism of glucose is a controlled combustion reaction that releases 2803 kJ of energy. Complete and balance the thermochemical equation below:

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

a) Use dimensional analysis to calculate how many kJ of heat are released when 6.44 moles of glucose combust.

b) Use dimensional analysis to calculate how many kJ of heat 100.75 grams of glucose will produce.

18) During the cooling of a sample of water from 65.0° C to 30.0° C, the water loses 1,570 joules of heat energy. What is the mass of this sample of water?

19) When 435 J of heat energy is added to 3.40 g of olive oil at 21.0° C, the temperature increases to 85.0° C. Calculate the specific heat of the olive oil.

20) An unknown solid with a mass of 14.4 g was heated to 94.5°C and placed in a calorimeter that contained 60.1 g of water at 20.5° C. The final temperature of both the water and the unknown solid was 30.5° C. Calculate the specific heat of the solid substance.

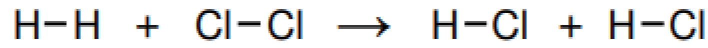
The system is the ______________. The surroundings is the ______________.

m_{system}		$m_{surroundings}$	
C_{system}		$C_{surroundings}$	
$T_{initial, system}$		$T_{initial, surroundings}$	
$T_{final, system}$		$T_{final, surroundings}$	
ΔT_{system}		$\Delta T_{surroundings}$	
q_{system}		$q_{surroundings}$	

Show your work for #20 here....

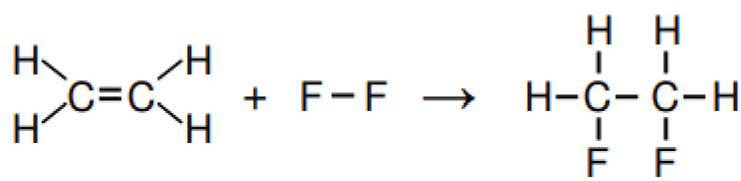
21) Using your bond energy handout, calculate ΔH for the reaction. Then, determine if the reaction is endothermic or exothermic.

$H_2(g) + Cl_2(g) \rightarrow 2\ HCl(g)$ ΔH = __________ *Endothermic / Exothermic*



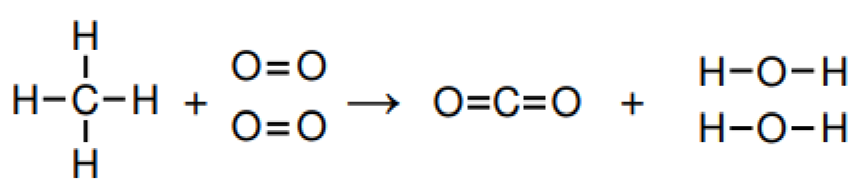
22) Using your bond energy handout, calculate ΔH for the reaction. Then, determine if the reaction is endothermic or exothermic.

$C_2H_4(g) + F_2(g) \rightarrow C_2H_4F_2(g)$ ΔH = __________ *Endothermic / Exothermic*



23) Using your bond energy handout, calculate ΔH for the reaction. Then, determine if the reaction is endothermic or exothermic.

$CH_4(g) + 2O_2(g) \rightarrow CO_2(g) + 2H_2O(g)$ ΔH = __________ *Endothermic / Exothermic*



Standard Heats of Formation (ΔH_f^0) for various substances					
Substance	ΔH_f^0 (kJ/mol)	Substance	ΔH_f^0 (kJ/mol)	Substance	ΔH_f^0 (kJ/mol)
$NaOH_{(s)}$	-426.7	$H_2S_{(g)}$	-20.1	$CH_{4\,(g)}$	-74.8
$HCl_{(g)}$	-92.3	$H_2O_{(g)}$	-241.8	$CO_{2\,(g)}$	-393.5
$NaCl_{(s)}$	-411.0	$H_2O_{(l)}$	-285.8	$SO_{2\,(g)}$	-296.1

24) Given the information at the top of this page, determine ΔH^0 for the reaction:

$2H_2S_{(g)} + 3O_{2\,(g)} \rightarrow 2H_2O_{(l)} + 2SO_{2\,(g)}$ ΔH^0 = ______________________

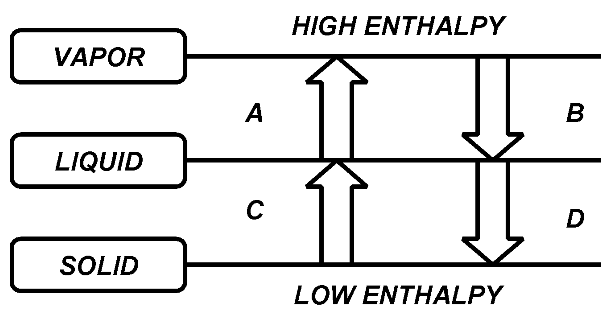
25) Given the information at the top of this page, determine ΔH^0 for the reaction:

$CH_{4\,(g)} + 2O_{2\,(g)} \rightarrow CO_{2\,(g)} \quad 2H_2O_{(g)}$ ΔH^0 = ______________________

Enthalpies of Physical State Changes

Use the figure to the right to answer questions #27 - 34

Continues onto the next page



26) ______ Arrow “A” indicates the heat absorbed by one mole of a substance as it boils to a vapor. This quantity is the ___.

a) molar heat of fusion
b) molar heat of solidification
c) molar heat of condensation
d) molar heat of vaporization

27) ______ Arrow “D” indicates the heat released when one mole of a substance freezes to a solid. This quantity is the ___.

a) molar heat of fusion
b) molar heat of solidification
c) molar heat of condensation
d) molar heat of vaporization

28) ______ The symbol that accompanies arrow “C” is ___.

a) ΔH_{vapor} b) ΔH_{fus} c) ΔH_{cond} d) ΔH_{solid}

29) ______ The symbol that accompanies arrow “B” is ___.

a) ΔH_{vapor} b) ΔH_{fus} c) ΔH_{cond} d) ΔH_{solid}

30) ______ Phase changes that release heat into the surroundings are exothermic and have a negative ΔH. Which of these symbols will be negative?

a) ΔH_{vapor} and ΔH_{fus}
b) ΔH_{fus} and ΔH_{cond}
c) ΔH_{cond} and ΔH_{solid}
d) ΔH_{cond} and ΔH_{vapor}

31) ______ Phase changes that absorb heat from the surroundings are endothermic and have a positive ΔH. Which of these symbols will be positive?

a) ΔH_{vapor} and ΔH_{fus}
b) ΔH_{fus} and ΔH_{cond}
c) ΔH_{cond} and ΔH_{solid}
d) ΔH_{cond} and ΔH_{vapor}

32) ______ During a phase change, the temperature of the substance undergoing the phase change ___

a) Increases
b) decreases
c) remains unchanged

33) ______ The molar heat of condensation, ΔH_{cond}, of water is -40.7 kJ/mol. What is the molar heat of vaporization, ΔH_{vapor}, of water?

a) -40.7 kJ/mol
b) +40.7 kJ/mol
c) +4.184 kJ/mol
d) Cannot be determined from information given.

Heating Curves -- *Complete your work on another sheet of paper for the following heat curve problems. Sketching an image like the one below might help you strategize each calculation!*

Substance	Melting Point (℃)	Vaporization Point (℃)	Specific Heat (J/g℃)	ΔH_{fus} (kJ/mol)	ΔH_{vap} (kJ/mol)
Ammonia (NH_3)	-77.73	-33.34	4.69	5.65	23.4
Ethanol (C_2H_5OH)	-114.1	78.37	2.46	4.60	43.5

34) How many kilojoules of heat are released when 15.5g of liquid ethanol freezes?

35) How much heat energy, in kJ, is absorbed when 46.0g of liquid ammonia vaporizes?

36) What is the total amount of heat energy, in kJ, required to change the temperature of 35.5g of liquid ammonia at -65.0℃ to gaseous ammonia at 0.00℃?

37) How much heat energy, in kJ, would be released from a 250.0g sample of ethanol that is cooled from 100.0℃ to -150.0℃?