

Chemistry

Unit 9

Thermodynamics,

Kinetics,

& Equilibrium

Thermodynamics/Kinetics/Equilibrium Unit Notes

Phases:

_____ = a part of matter what is uniform Solid, Liquid, Gas

Equilibrium = _____

- Products are being made in _____ directions at the _____ rate

Phase Changes	
	Solid → liquid
	Gas → liquid
	Solid → gas
	Liquid → solid
	Gas → solid
	Liquid → gas

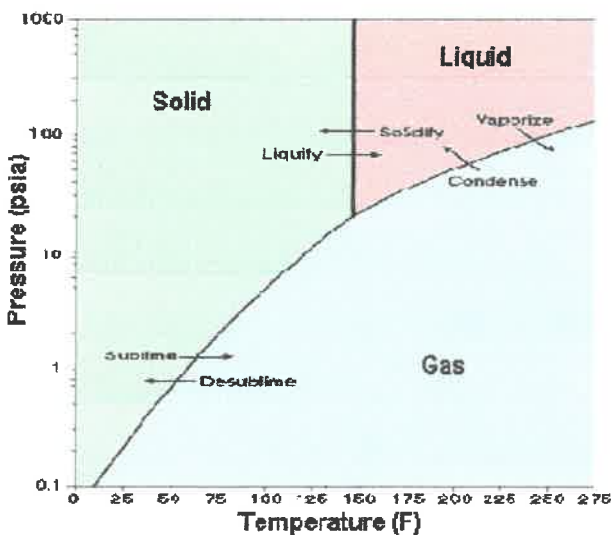
Vocabulary:

Vapor pressure – the partial pressure exerted by a vapor that is in _____ with its _____ state

- _____ exerted by those molecules trying to escape
- When _____ = _____ → Boiling
- As temperature increases, vapor pressure will _____

Phase Diagrams

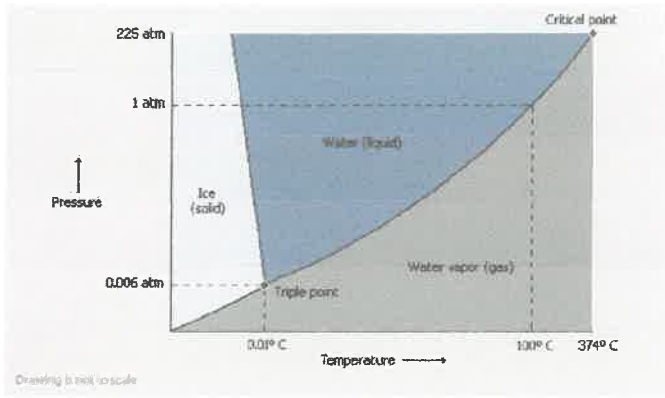
- Graph of the relationship between the _____ of a particular substance and the _____ and _____ of the substance
- Used to predict the _____ of a substance at any given _____ and pressure



Triple point: temperature and pressure where the solid, liquid, and gas phases of a substance coexist at _____.

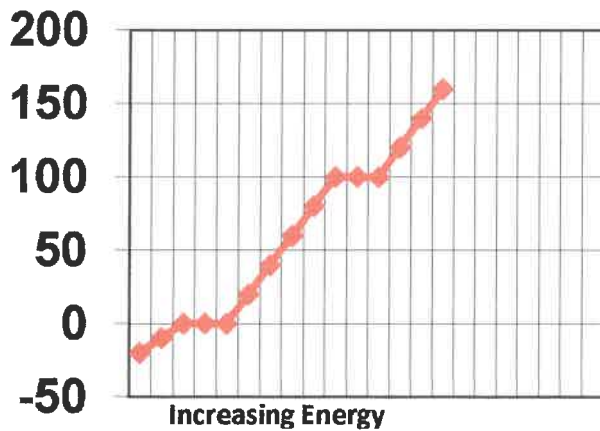
Critical point: The T and P where the gas and liquid state become identical and form one _____.

Supercritical fluid – state that a substance is in when the liquid and vapor phases are indistinguishable.



Heat Curves

- Shows us the point at which a substance _____ and _____
- Heat em' up, _____
 - _____



Energy Transfer

- If I have a cup of hot water and a cup of cold water, which will dissolve a spoon of sugar faster?
- WHY?

Vocabulary

- _____ – the capacity to do work
- **Heat** – the _____ between objects that are at different temperatures
- _____ – unit of energy
- _____ – a measure of how hot or cold something is; a measure of the _____ of _____ the particles of an object

_____ and _____ are different. If 2 samples at different temperatures are in contact, _____ can be transferred as _____.

- _____ – does not depend on the amount of a sample; doesn't change when you take away some of the sample
 - _____, color, melting point, boiling point, molecular weight and density
- _____ – does depend on the amount of a sample
 - Mass, length, volume, _____

All matter contains _____. Measuring the total amount of energy present is impossible, but _____ in energy content can be determined.

- Measure the _____ that enters or leaves the sample of matter

ENTHALPY - A substances energy

- Symbol = _____
- _____ content of a sample
 - The change in enthalpy is the _____ at a constant pressure.
 - Enthalpy is used to predict the _____.
 - _____ ΔH or ΔH_f is the change in the enthalpy that occurs during a chemical reaction.
 - Example: If 73 J of energy enter a piece of silver and no change in pressure occurs, we know the enthalpy of the silver has increased by 73 J.
 - If ΔH is positive– heat is absorbed (_____)
 - Feels cool to the touch EX _____
 - If ΔH is negative– heat is released (_____)
 - Feels warm to touch EX _____

Specific Heat = _____

- Symbol _____
- Units _____
- Calculating specific heat

$$q = mc \Delta T$$

q = heat (J)

m = amount in grams (g)

c (little c) = specific heat capacity (J/g°C or J/gK)

ΔT = change in temperature (°C or K)

- A positive q value indicates that the object gained thermal energy from its surroundings, and a positive ΔH value. (ENDOTHERMIC)
- A negative q value indicates that the object released thermal energy to its surroundings, and a negative ΔH value. (EXOTHERMIC)

- Example: How much heat is given off by a 50 g sample of copper when it cools from 80°C to 60°C . The specific heat of copper is $0.382\text{ J/g}^{\circ}\text{C}$.

- Example: A 15.75-g piece of iron absorbs 1086.75 joules of heat energy, and its temperature changes from 25°C to 175°C . Calculate the specific heat capacity of iron.

- To what temperature will a 50.0 g piece of glass raise if it absorbs 5275 joules of heat and its specific heat capacity is $0.50\text{ J/g}^{\circ}\text{C}$? The initial temperature of the glass is 20.0°C

Kinetics

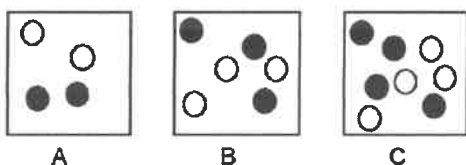
- Some reactions occur very quickly. Such as explosions and Fireworks
- Some reactions occur very slowly such as Rust
- **CHEMICAL KINETICS** – _____

Collision Theory suggests that a _____

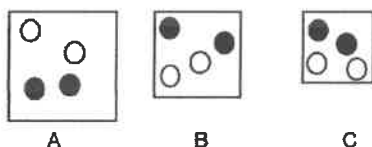
1. The reactants collide.
2. The collision occurs with a certain minimum energy, known as _____
3. The collision has the correct collision _____.

■ Factors affecting Collisions and Rate of Reaction

- _____ - Increasing the reactants concentration (from A to B to C) increases the collision frequency leading to a _____ rate of reaction.



- _____ - Increasing the pressure of a gas can be achieved by reducing its volume (from A to B to C) while leaving the number of particles the same.

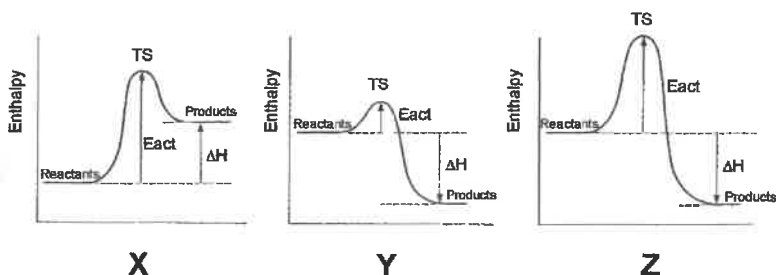


- _____ - increase the temperature will result in an _____ rate of reaction.
 - As a guideline in many reactions a 10°C rise will result in an approximate doubling of the rate. WHY?
- _____

A solid only reacts with the particles on the surface.

- **THE AMOUNT OF EXPOSED AREA TO REACT**
- **IF YOU INCREASE THE SURFACE AREA, THE REACTION RATE WILL** _____
- **↑ SURFACE AREA : ↑ RATE**
- Little pieces of metal will react much faster than one big block of metal

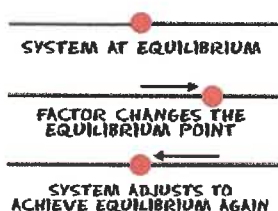
Activation Energy – _____



- Catalysts – Substances that _____ the rate of a reaction while remaining _____ . Lowers the _____ .
 - Remember Enzymes from Biology?

EQUILIBRIUM

- State of balance in which the rate of _____ equals the rate of _____
- Symbol _____
- Concentrations of products and reactants remain _____
- **LeChatelier's Principle**
 - If a chemical system at equilibrium experiences a change in _____ the equilibrium will shift in order to minimize that change



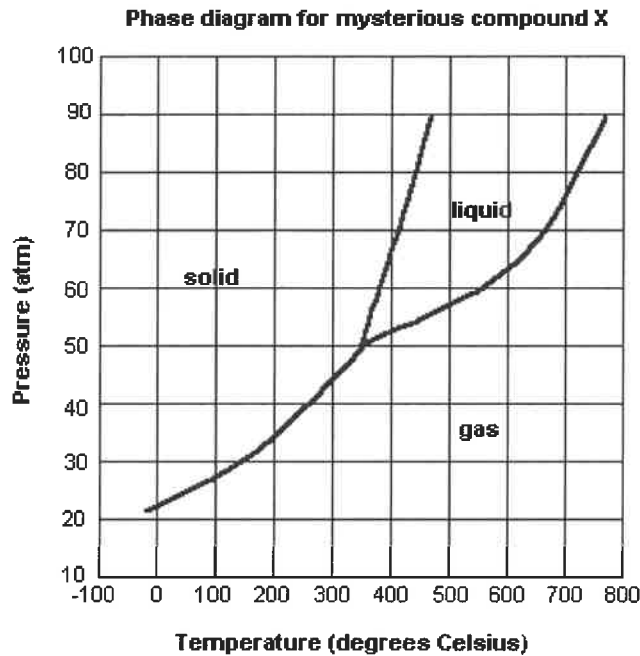
- Concentration $\text{H}_2 + \text{I}_2 \rightarrow 2\text{HI}$
 - If increase concentration of HI: reaction at equilibrium shifts the reaction to _____
 - Increase concentration of H_2 to the reaction at equilibrium shifts the reaction to _____
 - What if you decrease both concentrations...which direction will equilibrium shift?
- Temperature
 - Exothermic– is heat released as product or reactant?
 - Endothermic– is heat absorbed as a product or reactant?
 - $\text{NH}_4\text{NO}_3 + \text{H}_2\text{O} + 500\text{J} \rightarrow \text{NH}_4\text{OH} + \text{HNO}_3$
 - $\text{C}_6\text{H}_{12}\text{O}_6 + 6\text{O}_2 \rightarrow 6\text{CO}_2 + 6\text{H}_2\text{O} + 180\text{J}$
- Pressure – Only applies to _____
 - Increase in pressure favors the reactions that produces _____ gas molecules – which effectively decreases the stress (less collisions)



- What will an increase in pressure do to the equilibrium?
- There are cases where pressure will not affect equilibrium. $\text{H}_2\text{O} + \text{CO} \rightarrow \text{H}_2 + \text{CO}_2$

Phase Diagram Worksheet

For each of the questions on this worksheet, refer to the phase diagram for mysterious compound X.



- 1) What is the critical temperature of compound X? _____
- 2) If you were to have a bottle containing compound X in your closet, what phase would it most likely be in?

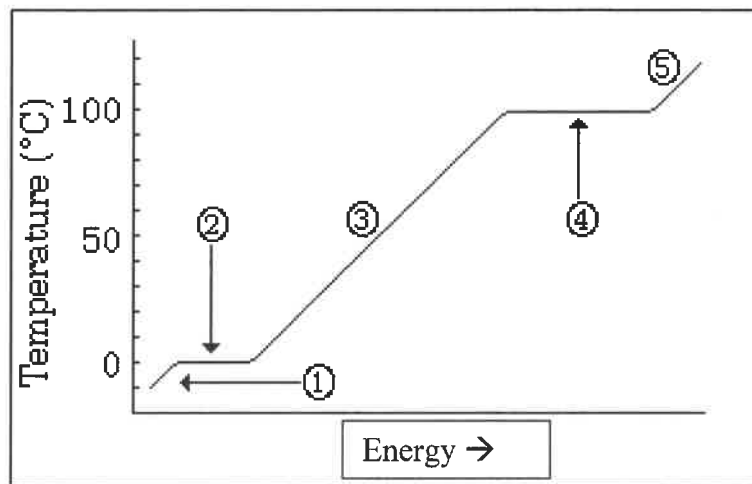
- 3) At what temperature and pressure will all three phases coexist?

- 4) If I have a bottle of compound X at a pressure of 45 atm and temperature of 100^o C, what will happen if I raise the temperature to 400^o C?

- 5) Why can't compound X be boiled at a temperature of 200^o C?

- 6) If I wanted to, could I drink compound X?

Heating Curve Review I Worksheet



- 1) What is happening to the average kinetic energy of the molecules in the sample during section 2? _____
- 2) As a substance goes through section (2), what happens to the distance between the particles? _____
- 3) What is the name of the process happening during section (4)? _____
- 4) What would be the name of the process happening during section (4) if energy were going the other way? _____
- 5) What is the melting point of this substance? _____
- 6) At what temperature would this sample finish boiling? _____
- 7) When this substance is melting, the temperature of the ice-water mixture remains constant because:
 - a. Heat is not being absorbed
 - b. The ice is colder than the water
 - c. Heat energy is being converted to potential energy
 - d. Heat energy is being converted to kinetic energy
- 8) When a given quantity of water is heated at a constant rate, the phase change from liquid to gas takes longer than the phase change from solid to liquid because
 - a. The heat of vaporization is greater than the heat of fusion
 - b. The heat of fusion is greater than the heat of vaporization
 - c. The average kinetic energy of the molecules is greater in steam than in water
 - d. Ice absorbs energy more rapidly than water does

Specific Heat Worksheet

$$q=mc\Delta T$$

$$\text{Units for specific heat} = \frac{\text{J}}{\text{g} \cdot ^\circ\text{C}}$$

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 10.0°C to 70.0°C ?
2. How many grams of water would require 2.20×10^4 joules of heat to raise its temperature from 34.0°C to 100.0°C ? The specific heat of water is $4.18 \text{ J/g}\cdot^\circ\text{C}$
3. If 200. grams of water is to be heated from 24.0°C to 100.0°C to make a cup of tea, how much heat must be added? The specific heat of water is $4.18 \text{ J/g}\cdot^\circ\text{C}$
4. A block of aluminum weighing 140. g is cooled from 98.4°C to 62.2°C with the release of 1080 joules of heat. From this data, calculate the specific heat of aluminum.
5. A cube of gold weighing 192.4g is heated from 30.0°C to some higher temperature, with the absorption of 226 joules of heat. The specific heat of gold is $0.030 \text{ J/g}\cdot^\circ\text{C}$. What was the final temperature of the gold?

6. A total of 54.0 joules of heat are absorbed as 58.3 g of lead is heated from 12.0°C to 42.0°C. From these data, what is the specific heat of lead?

7. The specific heat of wood is 2.03 J/g·°C. How much heat is needed to convert 550. g of wood at -15.0°C to 10.0°C?

8. What is the total amount of heat needed to change 2.25 kg of silver at 0.0°C to 200.0°C? The specific heat of silver is 0.129 J/g·°C

9. Granite has a specific heat of 800. J/g·°C. What mass of granite is needed to store 1.50×10^6 J of heat if the temperature of the granite is to be increased by 15.5°C?

10. A 55 kg block of granite has an original temperature of 15.0°C. What will be the final temperature of this granite if 4.5×10^4 kJ of heat energy are added to the granite?

Name _____ Period _____ Date _____

HOW CHEMICAL REACTIONS OCCUR

1. List the three steps that occur in every chemical reaction.
2. The substances going into a reaction are called _____. The substances formed in a reaction are called _____.
4. The energy required to start a chemical reaction is called _____, or _____.
5. What is kinetics?
6. List the 5 factors that affect the rate of a chemical reaction.
7. What is temperature? Explain IN DETAIL, how it affects a chemical reaction.
8. What is concentration? Explain IN DETAIL, how it affects a chemical reaction.
9. What is surface area? Explain IN DETAIL, how it affects a chemical reaction. (4)
10. How does stirring affects the rate of a chemical reaction.
11. What is a catalyst? How does it affect the rate of a chemical reaction? EXPLAIN.
12. What is enthalpy? What is the symbol that represents it?
13. Energy is measured in _____.
14. Explain what happens, in terms of energy, when:
 - (a) bonds are formed
 - (b) bonds are broken.
15. Fill in the following table: (6)

	exothermic	endothermic
heat/energy(out or in)		
feels		
ΔH		
16. Give an example of an exothermic reaction.
17. Give an example of an endothermic reaction. (4)
18. In a chemical reaction, the activation energy is the energy—
 - (a) required to break the bonds of the reactants
 - (b) released when product bonds are formed
 - (c) differences between the products and the reactants
 - (d) of a gas molecule at standard temperature and pressure
19. When a catalyst is added to a chemical reaction, which of the following occurs?
 - (a) the reaction will produce more products because the activation energy is lowered
 - (b) the reaction will produce more reactants because the activation energy is raised
 - (c) the reaction will be unaffected
 - (d) the reaction will slow down

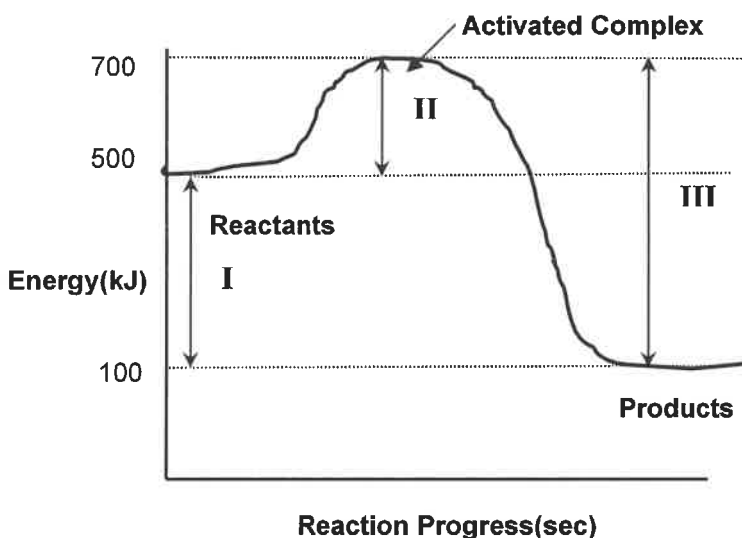
20. Which of the following is always true for an exothermic reaction? (2 answers are true)

- (a) ΔH is positive for the reaction
- (b) ΔH is negative for the reaction
- (c) the reaction will feel cold
- (d) the reaction will feel warm

21. Which of the following changes to a reaction will **always** cause an increase in the rate of the reaction?

- (a) an increase in the temperature and an increase in the concentration of the reactants.
- (b) an increase in the temperature and a decrease in the concentration of the reactants
- (c) a decrease in the temperature and an increase in the concentration of the reactants
- (d) a decrease in the temperature and a decrease in the concentration of the reactants

The remaining questions are based on the energy diagram:



22. Which of the following: I, II, or III, represent the activation energy for the forward reaction? _____

23. What is the activation energy (E_a) for the forward reaction? _____ kJ

24. Which of the following: I, II, or III, represent the activation energy for the reverse reaction? _____

25. What is the activation energy (E_a) for the reverse reaction? _____ kJ

26. State the Law of Conservation of Energy:

27. The forward reaction represented in the diagram is—

- (a) an endothermic reaction
- (b) an exothermic reaction
- (c) both endothermic and exothermic
- (d) neither endothermic nor exothermic

28. Which of the following will be changed by the addition of a catalyst that speeds up the forward reaction?

- (a) I only
- (b) II only
- (c) I and II only
- (d) I and III only

29. Which of the following represents the change in enthalpy for the forward reaction?

- (a) I only
- (b) II only
- (c) I and II together
- (d) III
- (e) both c and d

30. What will be the complete change in enthalpy (energy of the reaction or ΔH) for the forward reaction?

$$\Delta H = (\text{energy of products}) - (\text{energy of reactants})$$

31. Why is the symbol for ΔH negative for the forward reaction?

32. What will be the complete change in enthalpy (energy of the reaction or ΔH) for the reverse reaction?

$$\Delta H = (\text{energy of products}) - (\text{energy of reactants})$$

33. Why is the symbol for ΔH positive for the reverse reaction?

LE CHATELIER'S PRINCIPLE

Name _____

Complete the following chart by writing left, right or none for equilibrium shift, and decreases, increases or remains the same for the concentrations of reactants and products, and for the value of K.



Stress	Equilibrium Shift	[N ₂]	[H ₂]	[NH ₃]
1. Add N ₂	right	-	decreases	increases
2. Add H ₂				
3. Add NH ₃				
4. Remove N ₂				
5. Remove H ₂				
6. Remove NH ₃				
7. Increase Temperature				
8. Decrease Temperature				
9. Increase Pressure				
10. Decrease Pressure				

LE CHATELIER'S PRINCIPLE CONTINUED

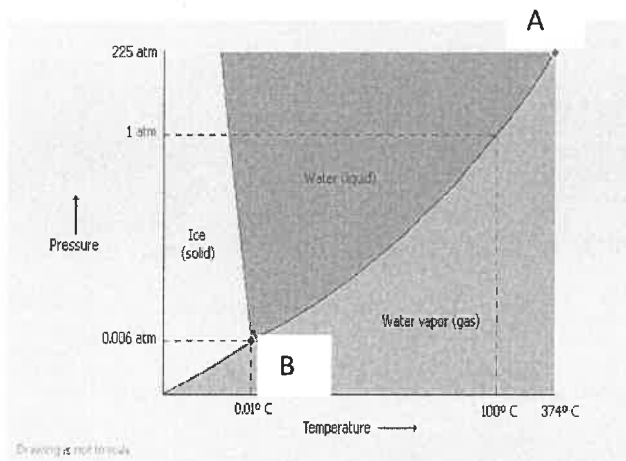
Name _____



Stress	Equilibrium Shift	[H ₂]	[I ₂]	[HI]
1. Add H ₂	right	_____	decreases	increases
2. Add I ₂			_____	
3. Add HI				_____
4. Remove H ₂		_____	..	
5. Remove I ₂			_____	
6. Remove HI				_____
7. Increase Temperature				
8. Decrease Temperature				
9. Increase Pressure				
10. Decrease Pressure				

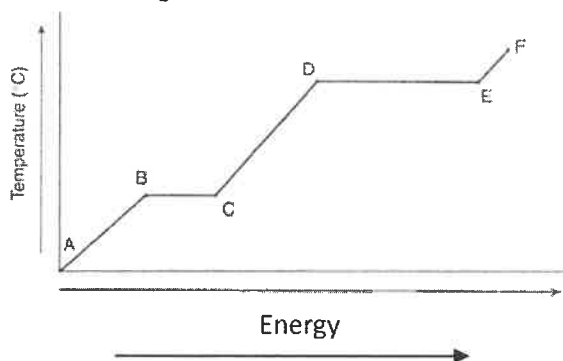
Thermodynamics, Kinetics, and Equilibrium Study Guide

A. Use the phase diagram below to answer the following questions. Assume that pressure is in **atm**.



1. The letter "A" represents the _____.
 2. The letter "B" represents the _____.
 3. If you are at 2 atm and -70 °C and you increase the temperature to 20 °C, what phase changes have occurred?
-
4. As you move from a solid to a gas, how many phase changes have occurred?

B. Use the heating curve below to answer the following questions.



5. Label the areas in which you have a solid, a liquid, and a gas on the chart.
6. The boiling point of the substance is represented by line segment ____.
7. The heating of the liquid is represented by line segment ____.
8. Vaporization will occur after line segment ____.
9. The heating of the solid is represented by line segment ____.
10. The melting point is represented by line segment ____.

C. Match each definition with the correct letter.

a. Triple point	b. Critical point
c. Supercritical Fluid	d. Enthalpy
e. Energy	f. Heat
g. Temperature	h. Phase
i. Phase Diagram	j. Boiling point
k. Equilibrium	l. Vapor pressure
m. Extensive property	n. Intensive property

11. ___ A property that is not affected by the size of the sample. Examples include temperature and color.
12. ___ The capacity to do work.
13. ___ Point where atmospheric equals vapor pressure.
14. ___ A part of matter that is uniform, such as solid, liquid, or gas.
15. ___ State that a substance is in when the liquid and vapor phases are indistinguishable.
16. ___ The partial pressure exerted by a vapor that is in equilibrium with its liquid state.
17. ___ The energy transferred between objects that are at different temperatures.
18. ___ A property that depends on the amount of sample you have. Examples include mass and volume.
19. ___ The temperature and pressure when the gas and liquid states become identical and form one phase.
20. ___ Total energy content of a sample.
21. ___ State where the forward and reverse processes happen at the same time.
22. ___ A measure of the average kinetic energy of the particles of an object.
23. ___ The temperature and pressure where the solid, liquid, and gaseous phases of a substance coexist at equilibrium.
24. ___ A graph of the relationships between the physical state of a substance and the temperature and pressure of that substance.

D. Complete the following specific heat problems

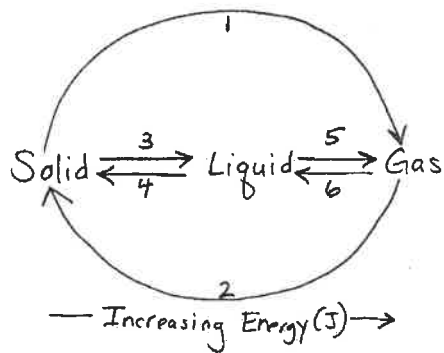
25. How many grams of water would require 2.20×10^4 joules of heat to raise its temperature from 34.0°C to 100.0°C ? The specific heat of water is $4.18 \text{ J/g}\cdot^\circ\text{C}$
26. A block of aluminum weighing 140. g is cooled from 98.4°C to 62.2°C with the release of 1080 joules of heat. From this data, calculate the specific heat of aluminum?

27. What is the total amount of heat needed to change 2.25 kg of silver at 0.0°C to 200.0°C? The specific heat of silver is 0.129 J/g·°C

28. Granite has a specific heat of 800. J/g·°C. What mass of granite is needed to store 1.50×10^6 J of heat if the temperature of the granite is to be increased by 15.5°C?

29. The specific heat of wood is 2.03 J/g·°C. How much heat is needed to convert 550. g of wood at -15.0°C to 10.0°C?

30. According to the Kinetic Molecular Theory of Matter, temperature is directly related to _____.



31. Which number represents:

- a. sublimation _____
- b. vaporization _____
- c. condensation _____
- d. evaporation _____
- e. freezing _____
- f. melting _____
- g. boiling _____

KINETICS

-THE STUDY OF REACTION RATES; HOW FAST A REACTION GOES

3. List the 5 factors that affect the rate of a chemical reaction

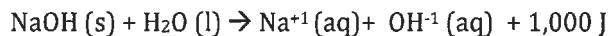
-
-
-
-
-

4. Next to the factors above, draw a picture to represent how the chemical reaction rate is affected when each of the above factors is increased (↑)

5. Fill in the following chart

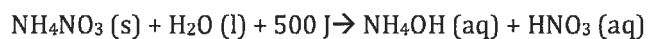
REACTION	FEELS?	HEAT IS A?	ΔH
EXOTHERMIC			
ENDOTHERMIC			

EXAMPLE 1



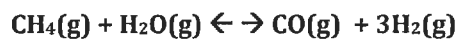
1. Is heat a reactant or a product?
2. What is the enthalpy (ΔH) for this reaction?
3. Would this reaction feel hot or cold?
4. Is this reaction exothermic or endothermic?

EXAMPLE 2:



1. Is heat a reactant or a product?
2. What is the enthalpy (ΔH) for this reaction?
3. Would this reaction feel hot or cold?
4. Is this reaction exothermic or endothermic?

Questions 5 – 7 refer to the reversible reaction shown below.



5. Which of the following changes will occur when CO gas is **added** to the reaction chamber?
 - a. There will be an increase in the concentration of CH₄
 - b. There will be an increase in the concentration of H₂
 - c. There will be a decrease in the concentration of CH₄
 - d. There will be a decrease in the concentration of H₂O

6. Which of the following changes to the equilibrium system will bring about an increase in the concentration of CO gas?
 - a. The addition of H₂ gas to the system
 - b. The removal of H₂O gas from the system
 - c. An increase in the temperature of the system
 - d. A decrease in the temperature of the system

7. If H₂O gas is removed from the system at equilibrium, which of the following will occur?
 - a. CH₄ concentration will increase and H₂ concentration will increase
 - b. CH₄ concentration will decrease and H₂ concentration will increase
 - c. CH₄ concentration will increase and H₂ concentration will decrease
 - d. CH₄ concentration will decrease and H₂ concentration will decrease

NOTES

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