ENERGY AND CHEMICAL REACTIONS

Do now: Write a definition of the following terms:
Exothermic reaction:

Endothermic Reaction:

Activation Energy:

Activity:
Record your observations for each of the following reactions. Predict if the reaction was endothermic, exothermic or demonstrated activation energy.

Demo 1: Sodium hydroxide in water

Demo 2: Ammonium nitrate in water

Demo 3: Burning a strip of magnesium

Demo 4: Sucrose in sulfuric acid

Demo 5: Ammonium chloride and barium hydroxide

Demo 6: Tide in water

Demo 7: Epsom salt in water

Closure:

1. Which reactions demonstrated endothermic reactions? Why?

2. Which reactions demonstrated exothermic reactions? Why?

3. Which reactions demonstrated activation energy? Why?

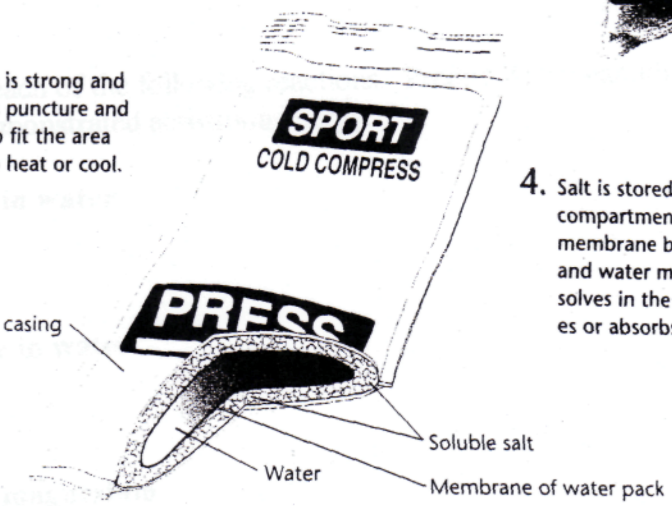
Applications:

Using these demonstrations as a guide, how do you think hot and cold packs work?

Hot and Cold Packs

Instant hot and cold packs create aqueous solutions that form exothermically or endothermically and therefore release or absorb heat. A hot pack generates heat when a salt such as calcium chloride dissolves in water that is stored in the pack. The calcium chloride dissolves exothermically. A cold pack absorbs heat when a salt such as ammonium nitrate dissolves in water. The ammonium nitrate dissolves endothermically. In both cases, the salt and water are separated by a thin membrane. All you have to do is squeeze the pack to mix the components and you have instant heat or cold at your fingertips.

1. The outer casing is strong and flexible. It resists puncture and can be shaped to fit the area that you want to heat or cool.



2. Water is stored in an inner compartment separate from the solid salt.

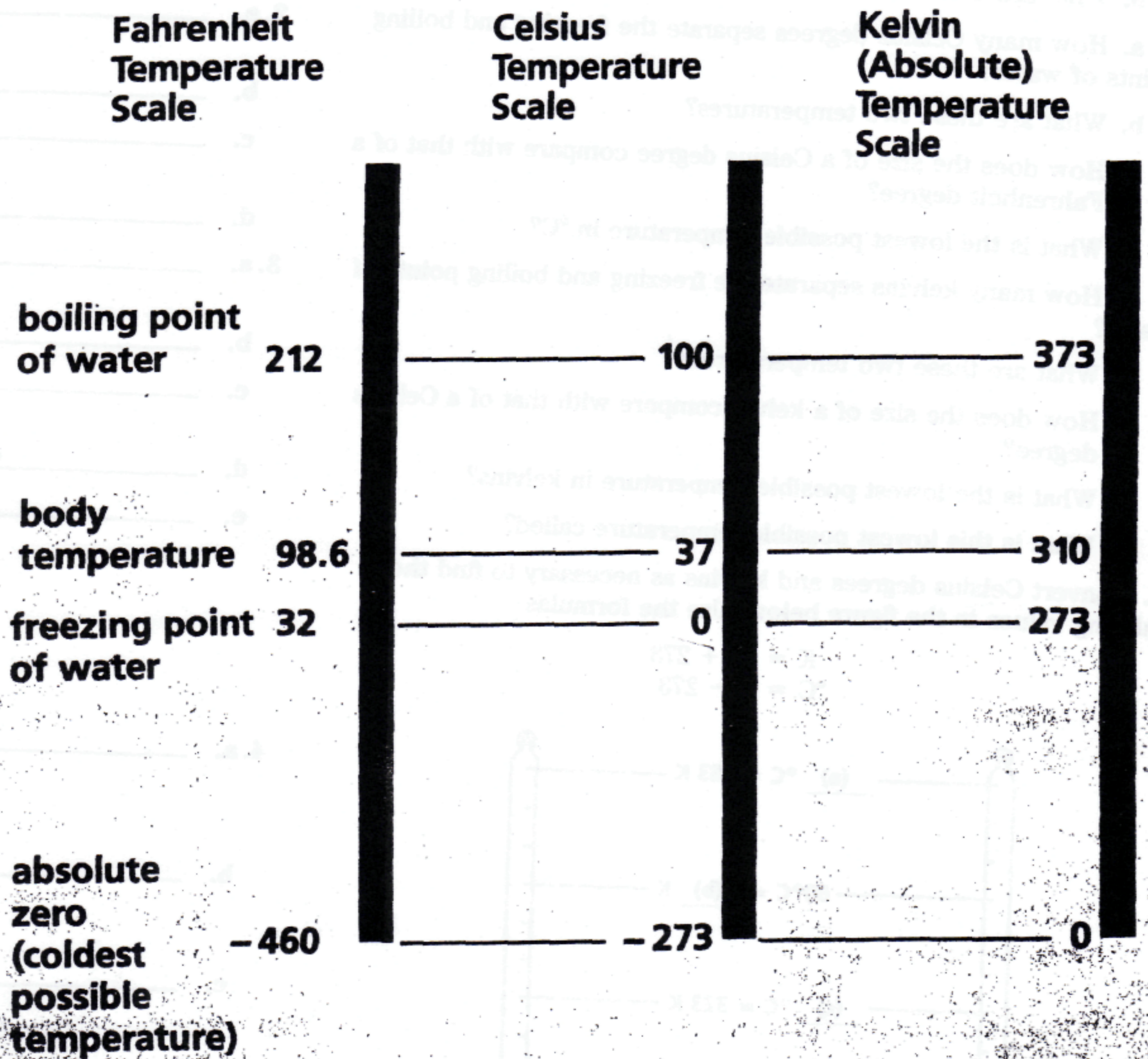
3. The inner membrane breaks easily when you knead or squeeze the pack or strike it sharply.

4. Salt is stored in the outer compartment. When the inner membrane breaks, the salt and water mix. The salt dissolves in the water and releases or absorbs energy.

Thinking Critically

1. Another type of hand warmer contains fine iron powder and chemicals that cause the iron to rust. The rusting of iron lets the hand warmer maintain temperatures above 60°C for several hours. Explain how that is possible.
2. When a solid in a cold pack dissolves in water, the process takes place spontaneously. What causes the solution process to be spontaneous in spite of the fact that it is endothermic?

A Comparison of Three Temperature Scales



Temperature

Answer the following questions.

1. a. How many Fahrenheit degrees separate the freezing and boiling points of water? **1. a.** ______________

   b. What are these two temperatures? **b.** ______________

2. a. How many Celsius degrees separate the freezing and boiling points of water? **2. a.** ______________

   b. What are these two temperatures? **b.** ______________

   c. How does the size of a Celsius degree compare with that of a Fahrenheit degree? **c.** ______________

   d. What is the lowest possible temperature in °C? **d.** ______________

3. a. How many kelvins separate the freezing and boiling points of water? **3. a.** ______________

   b. What are these two temperatures? **b.** ______________

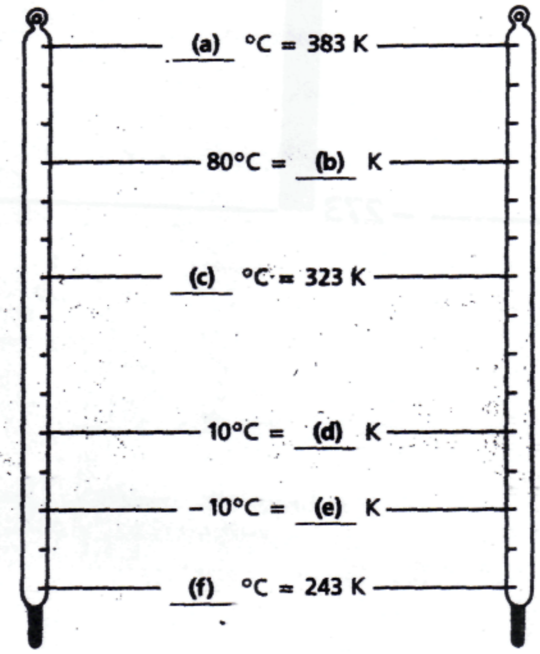
   c. How does the size of a kelvin compare with that of a Celsius degree? **c.** ______________

   d. What is the lowest possible temperature in kelvins? **d.** ______________

   e. What is this lowest possible temperature called? **e.** ______________

4. Convert Celsius degrees and kelvins as necessary to find the missing values in the figure below. Use the formulas

$$K = °C + 273$$
$$°C = K - 273$$



4. a. ______________

b. ______________

c. ______________

d. ______________

e. ______________

f. ______________

Specific Heat Worksheet

show __all__ work neatly.

write the heat equation & indicate what each symbol means.

1. If 4 grams of water at 1.0 °C absorbs 8 calories of heat, the temperature of the water will change by how many degrees?

2. How many ~~calories~~ joules of heat energy are absorbed when 100.0 grams of water is heated from 20°C to 30°C?

3. When 5.0 grams of water at 20.°C absorbs 10.0 calories of heat, the temperature of the water will increase by how much? What will the final temperature of the water be?

4. How many ~~calories~~ joules are needed to raise the temperature of 10.0 grams of water from 20°C to 30°C?

5. A 3000. gram mass of water in a calorimeter has its temperature raised 5.0 How much heat energy was transferred to the water? (joules + calories)

6. How many ~~calories~~ joules are required to heat 150. grams of water from 30.°C to 40.°C?

7. The temperature of water was raised 50.°C by the addition of 1000. calories. What is the mass of the water?

8. How much energy is required to change the temperature of a 1000. gram ice cube with an initial temperate of -15°C to -5°C. The specific heat of ice is .49 cal/ g °C.

9. 758 grams of PCl_3 is heated from 32 °C to 68 °C. What is the energy required to make this temperature change if the specific heat of phosphorus trichloride is .209 cal/g °C ? (joules)

10. 52.0 calories are required to raise the temperature of CCl_4 from 32.1 °C to 56.4 °C in a 10.35 gram sample. What is the specific heat of CCl_4?

Calorimetry

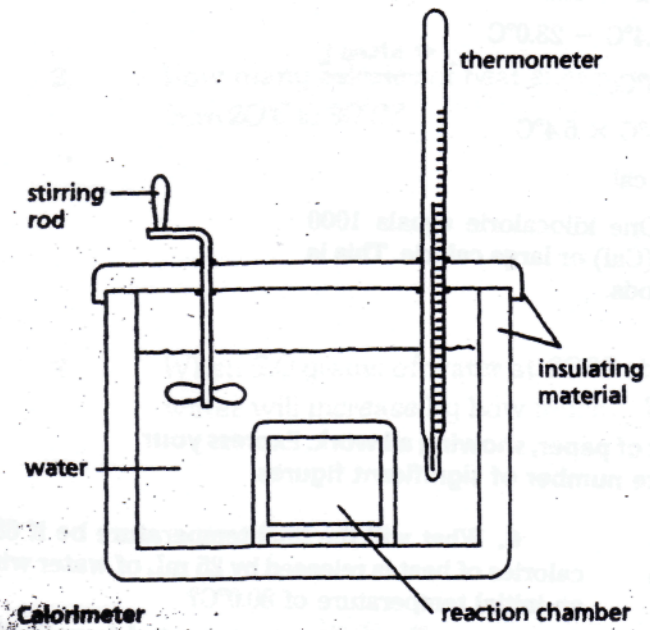
Answer the following questions.

1. a. The non-SI unit in which the quantity of heat energy has commonly been expressed is called the ___?___. **1. a.** __________

b. The SI-derived unit that is now the preferred unit for expressing this quantity is called the ___?___. **b.** __________

2. a. The quantity of heat energy required to raise the temperature of a unit mass of a substance by 1°C is called the ___?___ of the substance. **2. a.** __________

b. The value of this quantity for water, in SI-derived units, is ___?___. **b.** __________



3. a. In the calorimeter shown in the figure, a reaction that releases 8.4×10^3 J of heat energy takes place. Is this reaction endothermic or exothermic? **3. a.** __________

b. Assuming that the calorimeter contains 5.00×10^2 g of water and that the initial temperature is 30.0°C, what will the final temperature be? Choose your answer from among the following, and write the letter of the correct answer in the blank. **b.** __________

1. 4.0°C
2. 10.0°C
3. 26.0°C
4. 34.0°C
5. 40.0°C

Non-SI Supplementary Problems

A non-SI unit often used to express the amount of heat exchanged in a reaction is the calorie (cal). The calorie is defined as the amount of heat needed to raise 1 g of water 1 degree Celsius. Therefore the specific heat of water is equal to 1.00 cal/g-°C. The formula used to calculate calories is:

$$\text{calories} = mc\Delta T$$

where m = mass of the substance heated

c = the specific heat of the substance

ΔT = the temperature change of the substance

Example: How much heat energy is required to raise the temperature of 5.00×10^2 g of water from 23.0°C to 28.4°C?

calories = mass of H_2O × specific heat H_2O × change in temperature of H_2O

$$\text{Change in temperature } (\Delta T) = T_{final} - T_{initial}$$

$$= 28.4°C - 23.0°C$$

$$= 5.4°C$$

$$\text{heat} = 5.00 \times 10^2 \text{ g} \times 1.00 \text{ cal/g-°C} \times 5.4°C$$

$$= 27 \times 10^2 \text{ cal} = 2.7 \times 10^3 \text{ cal}$$

A larger unit of heat is the kilocalorie (kcal). One kilocalorie equals 1000 calories. The kilocalorie is also called the Calorie (Cal) or large calorie. This is the unit of measurement commonly used with foods.

Exercises

Solve the following problems on a separate sheet of paper, showing all work. Express your answers in the correct units with the appropriate number of significant figures.

1. How many calories of heat are required to raise the temperature of 1.00 kg of water from 10.2°C to 26.8°C?

2. How much heat is released when 275 grams of water cools from 85.2°C to 38.4°C? Express your answer in kcal.

3. What temperature change will 100.0 mL of water undergo when it absorbs 325 calories of heat?

4. What will the change in temperature be if 422 calories of heat is absorbed by 80.0 mL of water?

5. What will the final temperature be if 45.0 mL of water at 15.4°C absorbs 2.50×10^2 calories of heat?

6. What will the final temperature be if 688 calories of heat is released by 25 mL of water with an initial temperature of 80.0°C?

7. A quantity of water is heated from 25.0°C to 36.4°C by absorbing 325 calories. What is the mass of the water?

8. What is the mass of a sample of water that is heated from 10.0°C to 24.6°C while absorbing 1.00 kcal?

9. What is the specific heat of lead if a 30.0 g of lead undergoes a 250°C change while absorbing 229.5 calories?

10. A 1.00×10^3-g block of aluminum releases 6.450×10^3 calories as it cools from 55.0°C to 25.0°C. What is the specific heat of aluminum?

COMPARISON OF THE PHASES OF MATTER

CHARACTERISTIC	SOLID	LIQUID	GAS
Shape			
Volume			
Intermolecular Distances			
Intermolecular Forces of Attraction			
Average Kinetic Energy			
Molecular Velocities			
Tendency to diffuse			
Density			
Compressibility			

RULES FOR GRAPHING

1. Decide which variables will be plotted on each axis. The independent variable is plotted on the x (horizontal) axis and the dependent variable is plotted on the y (vertical) axis. Axis need to be labeled INCLUDING UNITS.

2. Select scales for both axis that reflect the precision of the measurements. To make the sale for your graph you need to know the range of your data (largest value-smallest value) and the length of your axis (number of boxes)

Divide range/# of boxes. This gives you the value of each box. Round up to a number that is easy to work with. For example if you get .45 per box, you would make each box worth .50.

3. After your data points have been plotted, draw a smooth line or curve that represents the line of best fit. Points will probably fall on both sides of the curve or line due to experimental error. If one point is a great distance from the curve, the data should be rechecked.

4. Appropriately title your graph.

5. Include a legend if more than one plot is on the same axes.

ACTIVITY: HEATING AND COOLING CURVES

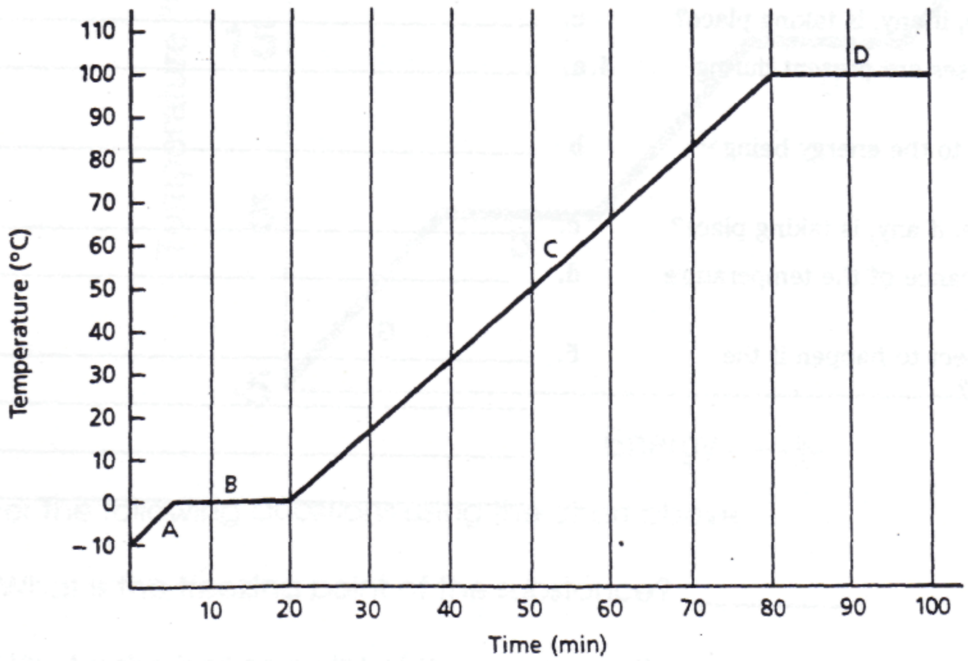
Practice graphing the following data for ice 600 grams of ice at -20 degrees Celsius:

Time (min)	Temperature(degrees Celsius)
0	-20
1	-10
5	-5
10	-2
15	0
20	0
25	0
30	0
35	5
40	20
45	40
50	63
55	74
60	92
65	100
70	100
75	100
80	100
85	103
90	105
95	110

Name ______________________ Date ____________ Class ____________

A Heating Curve

The heating curve shown in the figure is a plot of temperature *vs.* time. It represents the heating of what is initially ice at −10°C at a constant rate of heat transfer.



Answer the following questions.

1. a. What phase or phases are present during segment A? **1. a.** ____________________

b. What is happening to the energy being absorbed from the heat source? (Answer in terms of potential and/or kinetic energy.) **b.** ____________________

c. What phase change, if any, is taking place? **c.** ____________________

2. a. What phase or phases are present during Segment B? **2. a.** ____________________

b. What is happening to the energy being absorbed? **b.** ____________________

c. What phase change, if any, is taking place? **c.** ____________________

d. What is the significance of the temperature 0°C? **d.** ____________________

Name ______________________________

A Heating Curve (continued)

3. a. What phase or phases are present during segment C? 3. a. ____________

b. What is happening to the energy being absorbed? b. ____________

c. What phase change, if any, is taking place? c. ____________

4. a. What phase or phases are present during segment D? 4. a. ____________

b. What is happening to the energy being absorbed? b. ____________

c. What phase change, if any, is taking place? c. ____________

d. What is the significance of the temperature 100°C? d. ____________

5. What would you expect to happen if the heating were continued? 5. ____________

HEATING CURVE PROBLEMS

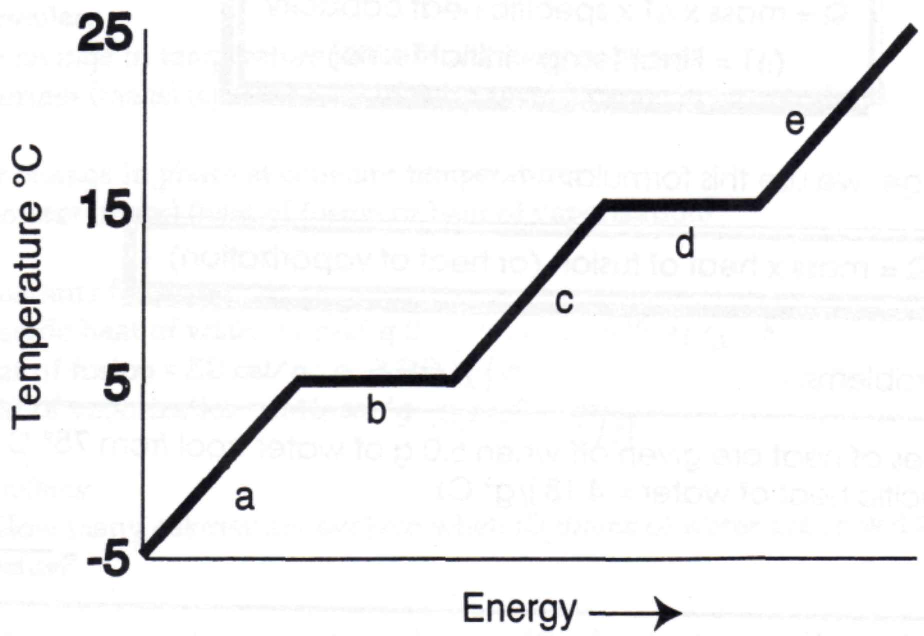
1. How many grams of ice can be melted by the addition o 5600 calories of heat?

2. Calculate the heat given off when 50 grams of steam are condensed at 100 degrees celcius and then frozen at 0 degrees celcius. (joules)

3. Calculate the quantity of heat needed to melt 70 grams of ice at 0 degrees and then boil the resulting water. (joules)

·EEZING AND BOILING ·OINT GRAPH

Name ______________



Answer the following questions using the chart above.

1. What is the freezing point of the substance? ________
2. What is the boiling point of the substance? ________
3. What is the melting poin·· ·f the substance? ________
4. What letter represents the range where the solid is being warmed? ________
5. What letter represents the range where the liquid is being warmed? ________
6. What letter represents the range where the vapor is being warmed? ________
7. What letter represents the melting of the solid? ________
8. What letter represents the vaporization of the liquid? ________
9. What letter(s) shows a change in potential energy? ________
10. What letter(s) shows a change in kinetic energy? ________
11. What letter represents condensation? ________
12. What letter represents crystallization? ________

Name

A Heating Curve (continued)

3. a. What phase or phases are present during segment C? **3. a.** ____

b. What is happening to the energy being absorbed? **b.** ____

c. What phase change, if any, is taking place? **c.** ____

4. a. What phase or phases are present during segment D? **4. a.** ____

b. What is happening to the energy being absorbed? **b.** ____

c. What phase change, if any, is taking place? **c.** ____

d. What is the significance of the temperature 100°C? **d.** ____

5. What would you expect to happen if the heating were continued? **5.** ____

HEATING CURVE PROBLEMS

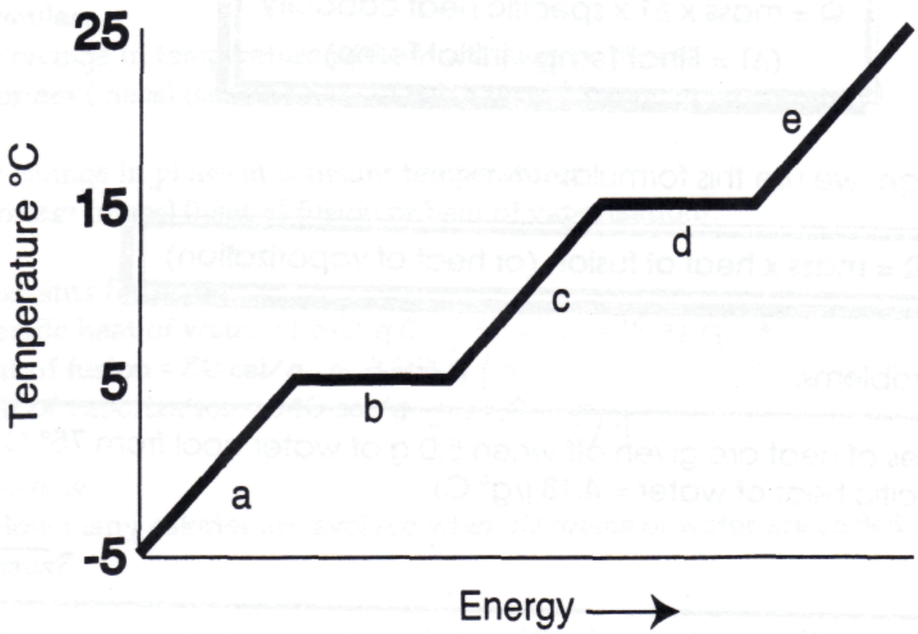
1. How many grams of ice can be melted by the addition o 5600 calories of heat?

2. Calculate the heat given off when 50 grams of steam are condensed at 100 degrees celcius and then frozen at 0 degrees celcius. (joules)

3. Calculate the quantity of heat needed to melt 70 grams of ice at 0 degrees and then boil the resulting water. (joules)

ꞮEEZING AND BOILING POINT GRAPH

Name ____________________



Answer the following questions using the chart above.

1. What is the freezing point of the substance? ________
2. What is the boiling point of the substance? ________
3. What is the melting point of the substance? ________
4. What letter represents the range where the solid is being warmed? ________
5. What letter represents the range where the liquid is being warmed? ________
6. What letter represents the range where the vapor is being warmed? ________
7. What letter represents the melting of the solid? ________
8. What letter represents the vaporization of the liquid? ________
9. What letter(s) shows a change in potential energy? ________
10. What letter(s) shows a change in kinetic energy? ________
11. What letter represents condensation? ________
12. What letter represents crystallization? ________

HEAT AND ITS MEASUREMENT

Name ____________________

Heat (or energy) can be measured in units of calories or joules. When there is a temperature change (ΔT), heat (Q) can be calculated using this formula:

$$Q = \text{mass} \times \Delta T \times \text{specific heat capacity}$$
$$(\Delta T = \text{Final Temp} - \text{Initial Temp})$$

During a phase change, we use this formula:

$$Q = \text{mass} \times \text{heat of fusion (or heat of vaporization)}$$

Solve the following problems.

1. How many joules of heat are given off when 5.0 g of water cool from 75° C to 25° C? (Specific heat of water = 4.18 j/g° C) ________

2. How many calories are given off by the water in Problem 1? (Specific heat of water = 1.0 cal/g° C) ________

3. How many joules does it take to melt 35 g of ice at 0° C? (heat of fusion = 333 j/g) ________

4. How many calories are given off when 85 g of steam condense to liquid water? (heat of vaporization = 539.4 cal/g) ________

5. How many joules of heat are necessary to raise the temperature of 25 g of water from 10° C to 60° C? ________

6. How many calories are given off when 50 g of water at 0° freezes? (heat of fusion = 79.72 cal/g) ________

PRACTICE PROBLEMS FOR HEATING AND COOLING CURVES

Formulas:
For change in temperature without a change in phase:
calories= (mass) (specific heat of substance) (change in temperature)

For change in phase at constant temperature:
calories= (mass) (heat of fusion or heat of vaporization)

Constants for water:
Specific heat of water = 1 cal/ g C = 4.2 joules/ g °K
Heat of fusion = 80 cal/g = 334 J/g
Heat of vaporization = 540 cal/g 2259 J/g

Problems:

1. How many calories are evolved when 10 grams of water are cooled 25 degrees Celsius?

2. How many calories must be added to 25g of water to raise its temperature from 0 to 50 degrees Celsius?

3. How many calories are required to melt 60 grams of ice at 0 degrees Celsius?

4. How much heat is evolved when 15 grams of water cools from 85 to 45 degrees Celsius? (joules)

5. How much heat is evolved when 15 grams of steam condenses at 100 degrees Celsius? (joules)

6. How much heat is required to boil 200 g of water at 100 degrees Celsius? (joules)

7. How many calories are required to melt 5.0 grams of ice at 0 degrees Celsius and raise the resulting temperature of the water 58 degrees Celsius?

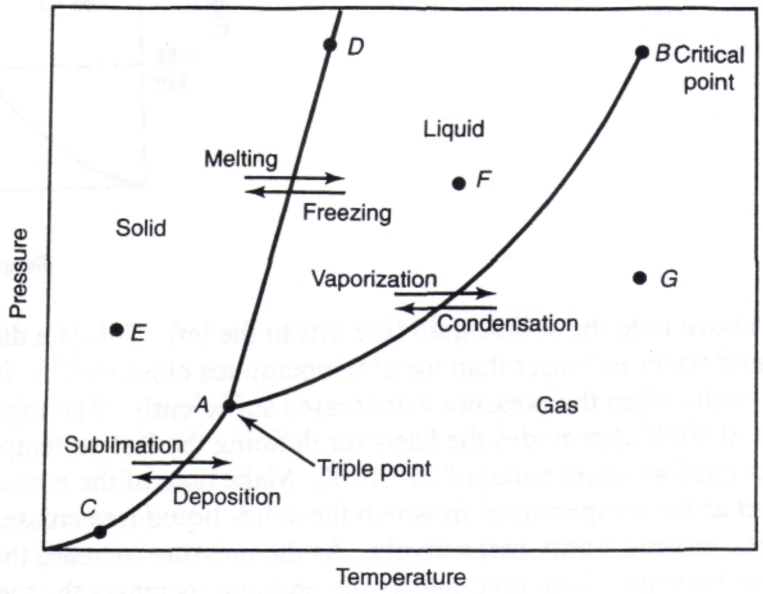
8. How much heat is given off when 30 grams of steam is condensed at 100 degrees Celsius and the resulting water is cooled to 35 degrees Celsius? (joules)

9. Calculate the amount of heat evolved when 25 grams of steam is condensed at 100 degrees and the water is frozen at 0 degrees Celsius? (joules)

10. How much heat is needed to melt 40 grams of ice at 0 degrees Celsius and then boil the resulting water at 100 degrees Celsius? (joules)

TRIPLE POINT DIAGRAM

Heating and cooling curves show the changes in temperature with the passage of time. The diagram below is known as a triple point diagram and is also a phase change diagram. It shows the combined effects of pressure and temperature on the physical state of a substance.



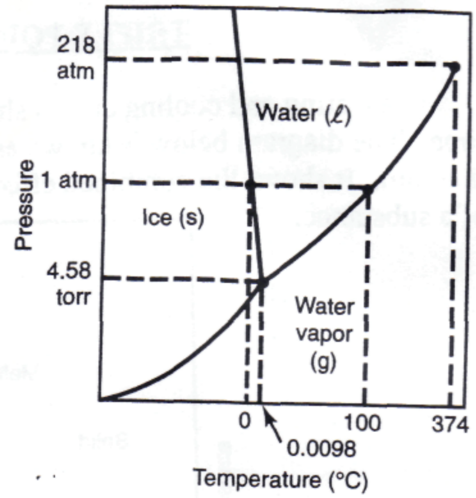
KEY

Each line represents the pressure-temperature combination at which two phases are in dynamic equilibrium.
Line CA (sublimation-deposition line): represents the conditions under which the solid and gas phase are in dynamic equilibrium.
Line AB (vaporization-condensation line): represents the conditions under which the liquid and gas phase are in dynamic equilibrium.
Line AD (melting-freezing line): represents the conditions under which the liquid and solid phase are in dynamic equilibrium.

At any combination of temperature and pressure that does not lie on one of the lines only one phase exists.
Point E: solid phase
Point F: liquid phase
Point G: gas phase

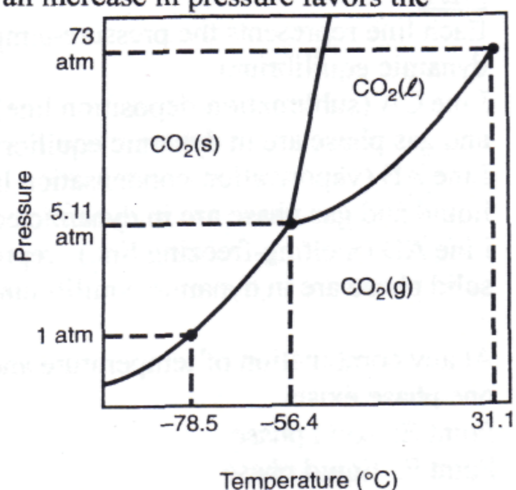
The phase diagram also includes two points of special interest.
Point A: **Triple point** (only point at which all three phases can coexist in dynamic equilibrium)
Point B: **Critical point** (the temperature and pressure at the critical point are known respectively as the critical temperature and critical pressure. Above the critical temperature only the gas phase can exist, no matter how high the pressure, because the kinetic energies of the gas particles are too high to allow the formation of a liquid.

The following are two actual triple point diagrams.
Diagram 1: Triple Point diagram for water:



In the diagram above note the solid-liquid line tilts to the left. This is a direct result of the fact that liquid water is denser than ice at temperatures close to 0^0c. It is also the reason why ice melts when the pressure is increased sufficiently. The triple point of water (4.58 torr, 0.0098^0c) provides the basis for defining the Kelvin temperature scale. This point is assigned an exact value of 273.16 K. Make note of the normal melting point and boiling point as the temperatures in which the solid- liquid line crosses 1 atm. And the liquid-gas line crosses 1 atm. respectively. As the pressure increase the boiling point of water will also increase. Also note that as the pressure increases the melting point decreases. This is unusual and is related to the fact that an increase in pressure favors the formation of the denser (liquid) phase.

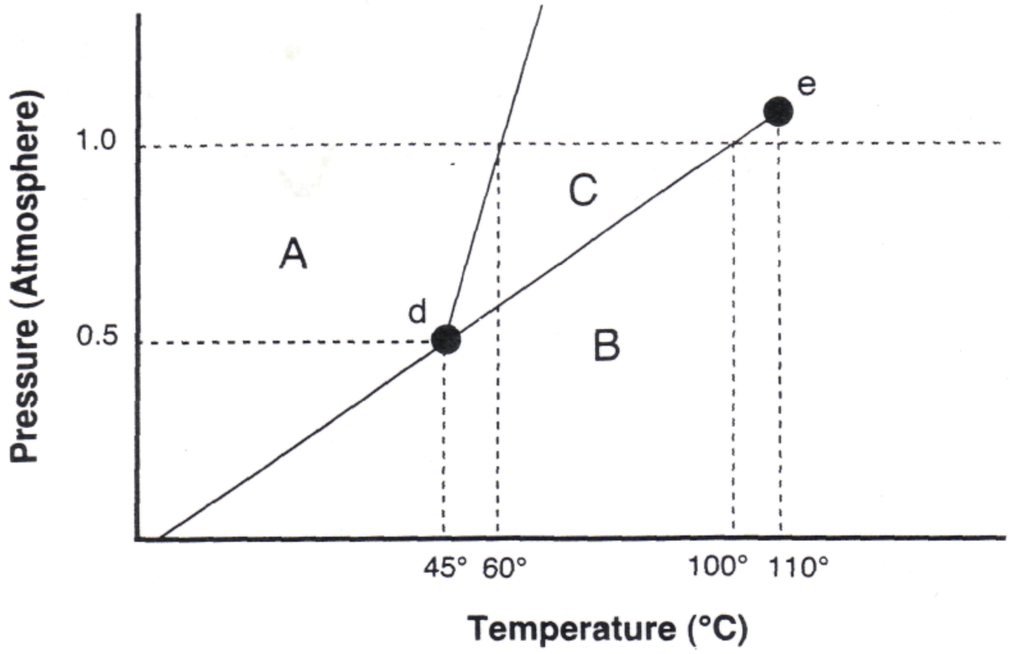
Diagram 2: Triple Point diagram for carbon dioxide:



The above phase change diagram has the same appearance as the general phase diagram because solid carbon dioxide is denser than the liquid phase. Also note that at a constant pressure of 1 atm., carbon dioxide passes directly from the solid to the gas phase as the temperature is increased; the liquid phase does not even come into existence until the pressure reaches 5.11 atm.

PHASE DIAGRAM

Name ______________



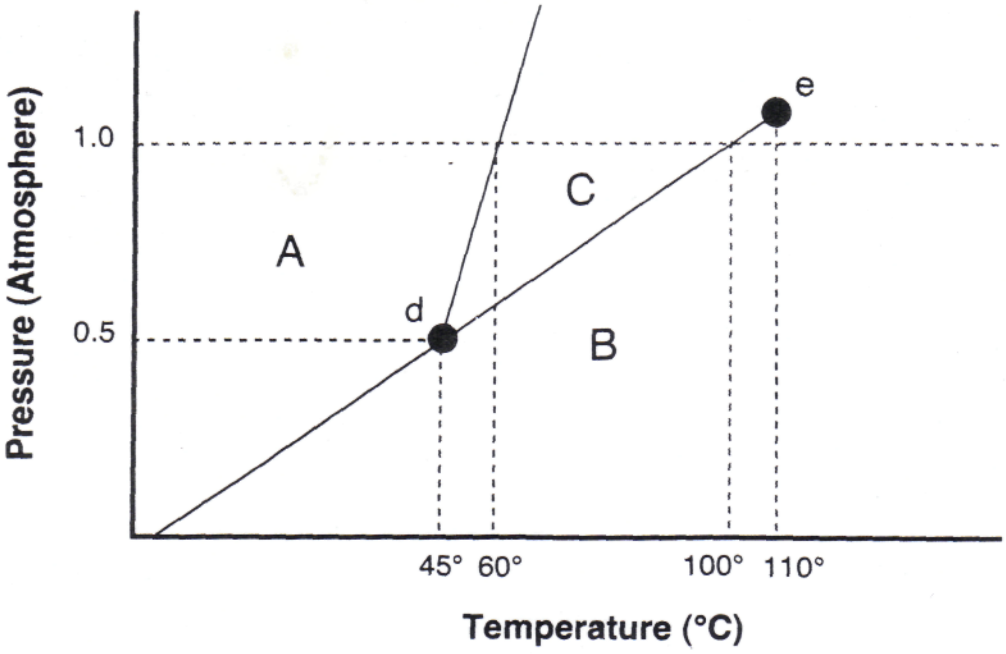
Answer the following questions using the chart above.

1. What section represents the solid phase? __________
2. What section represents the liquid phase? __________
3. What section represents the gas phase? __________
4. What letter represents the triple point? __________
5. What letter represents the critical point? __________
6. What is this substance's normal melting point? __________
7. What is this substance's normal boiling point? __________
8. Above what temperature is it impossible to liquify this substance no matter what the pressure? __________
9. At what temperature and pressure do all three phases coexist? __________
10. Is the density of the solid greater than or less than the density of the liquid?

    ____
11. Would an increase in pressure cause this substance to freeze or melt? __________

PHASE DIAGRAM

Name ____________



Answer the following questions using the chart above.

1. What section represents the solid phase? ________
2. What section represents the liquid phase? ________
3. What section represents the gas phase? ________
4. What letter represents the triple point? ________
5. What letter represents the critical point? ________
6. What is this substance's normal melting point? ________
7. What is this substance's normal boiling point? ________
8. Above what temperature is it impossible to liquify this substance no matter what the pressure? ________
9. At what temperature and pressure do all three phases coexist? ________
10. Is the density of the solid greater than or less than the density of the liquid? ________
11. Would an increase in pressure cause this substance to freeze or melt? ________

