Exercise 10.5a
Enthalpy of Fusion & Vaporization

Name: ______________________

Date:________________ Per:________

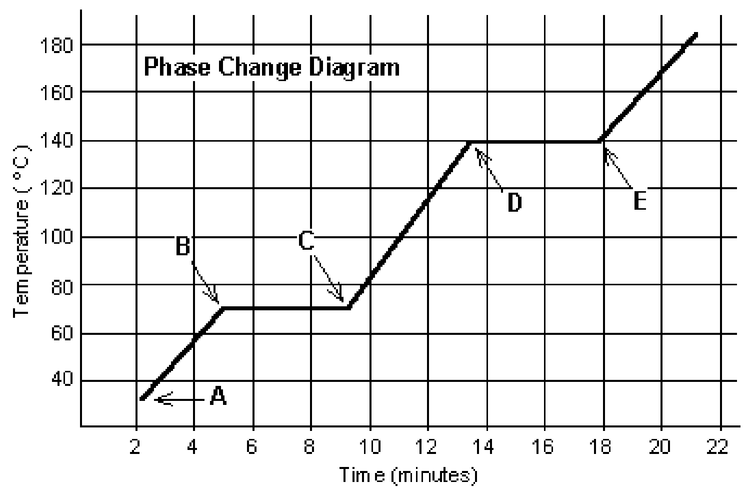
A change in enthalpy (ΔH) is a measurement of energy transfer in the form of heat. Energy may be gained from the surrounding environment by a substance (or system) in an endothermic process (+ΔH), removing heat (i.e., cooling) the surrounding environment. Energy may also be released to the surrounding environment by a substance (or system) in an exothermic process (-ΔH), causing heating of the surrounding environment.

During a phase change the temperature of the substance does not change. Energy is either being absorbed by a substance to overcome intermolecular forces and spread the particles out or is being released as the potential energy of separated particles is converted to motion and particles are drawn together into more condensed arrangements.

Enthalpy of fusion (energy necessary to break solids into liquids) and enthalpy of fusion (energy necessary to separate liquids into gases) may be expressed per gram of substance (kJ/g) or per mole of substance(kJ/mol). The values for water are:

$\Delta H_{(fus)}$ for H_2O is 6.02 kJ/mol | $\Delta H_{(vap)}$ for H_2O is 40.7 kJ/mol

Directions: *The graph was drawn from data collected as a substance was heated at a constant rate. Use the graph to answer the following questions.*



At **(A)** the substance exists in a _____solid______ state. Material in this phase has ____definite____ volume and ______definite _____ shape. As ____heat______ is added to the substance, the particles of the substance ____vibrate_____ more rapidly causing the ___temperature___ to rise. At **(B)** the temperature of the substance is __≈70__°C. This represents the ___melting_____ point of the substance. Between **(B)** and **(C)** temperature remains ____constant___ as energy is added to the substance. The energy breaks __intermolecular__ forces and increases the substance's ___potential__ energy. At **(C)** the substance has completely ___melted_____ and exists in a ____liquid___ state. Material in this phase has ____definite______ volume and ____indefinite___ shape. The energy added to the substance between **(B)** and **(C)** was used to convert the substance from a ____solid____ to a ____liquid___. This heat energy is called the ***enthalpy of fusion***. Between **(C)** and **(D),** as heat is added, the ____temperature__ increases indicating an increase in ___kinetic____ energy of the substance. At point **(D)** the temperature of the substance is ___140__ °C and the substance has reached its ____boiling___ point. Additional heat added to the substance after **(D)** breaks ___ intermolecular__ forces and increases the substance's ______potential____ energy. The energy involved in the change from **(D)** to **(E)** is __much greater___ than the energy involved in the change from **(B)** to **(C)**. The change between **(D)** and **(E)** is called ___vaporization__. At **(E)**, the substance is completely in the _____gaseous_____ phase. Material in this phase has ___indefinite_____ volume and ___indefinite___ shape. The energy added to the substance between **(D)** and **(E)** converted the substance from a ____ liquid_____ to a ____gaseous_____ state. This energy is called the ***enthalpy of vaporization***. Beyond **(E)**, the substance is in the ______gaseous____ phase and added heat causes the particles to move __more rapidly_ as indicated by the increasing temperature. In summation, the sloped regions of the graph represent changes in ____kinetic_____ energy causing particles to ____move more rapidly____, and the level regions of the graph represent changes in ___potential____ energy causing particles to ___separate from one another___.

Which of these three substances was likely used in this phase change experiment? _Z_

Substance	Melting point	Boiling point
X	20 °C	100 °C
Y	40 °C	140 °C
Z	70 °C	140 °C

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Calculating the change in enthalpy of a substance as it goes through a phase change is a simple process of multiplying the amount of substance expressed in either moles or grams by the appropriate enthalpy of phase change. Heat energy may be gained or released during a phase change, so the sign (+/–) used to express the change in enthalpy (ΔH) is critical. While the heat of fusion of water ($\Delta H_{(fus)}$) is +6.02 kJ/mol, due to it being an endothermic process, the heat of solidification ($\Delta H_{(sol)}$) is an exothermic process and energy must be indicated to be leaving the system by using the negative value (–6.02 kJ/mol).

$\Delta H_{(fus)}$ for H_2O is 6.02 kJ/mol | $\Delta H_{(vap)}$ for H_2O is 40.7 kJ/mol

***Directions:** The graph was drawn from data collected as a substance was heated at a constant rate. Use the graph to answer the following questions.*

1. Calculate the enthalpy of fusion for water in J/g.

$$\frac{6.0\underline{2}\ \cancel{kJ}}{1\ \cancel{mol\ H_2O}} \times \frac{1\ \cancel{mol\ H_2O}}{18.01\underline{5}\ g\ H_2O} \times \frac{1000\ J}{1\ \cancel{kJ}} = 33\underline{4}.16\ J/g \quad \boxed{334\ J/g}$$

2. Calculate the enthalpy of vaporization for water in cal/gram (1 calorie (cal) = 4.184J).

$$\frac{40.\underline{7}\ \cancel{kJ}}{1\ \cancel{mol\ H_2O}} \times \frac{1\ \cancel{mol\ H_2O}}{18.01\underline{5}\ g\ H_2O} \times \frac{1000\ \cancel{J}}{1\ \cancel{kJ}} \times \frac{1\ cal}{4.18\underline{4}\ \cancel{J}} = 53\underline{9}.96\ cal/g \quad \boxed{540.\ cal/g}$$

3. Calculate the enthalpy change of 50.0 grams of condensing water vapor?

$$\frac{50.\underline{0}\ \cancel{g\ H_2O}}{} \times \frac{1\ \cancel{mol\ H_2O}}{18.01\underline{5}\ \cancel{g\ H_2O}} \times \frac{-\ 40.\underline{7}\ kJ}{1\ \cancel{mol\ H2O}} = -\ 11\underline{2}.96\ cal/g \quad \boxed{-\ 113\ kJ}$$

(Since water is condensing instead of vaporizing, the ΔH is negative ($\Delta H_{(con)}$).)

4. How much energy is needed to melt 12.4 g of lead? ($\Delta H_{(fus)}$ = 22.4 J/g)

$$\frac{12.\underline{4}\ \cancel{g\ Pb}}{} \times \frac{22.\underline{4}\ J}{1\ \cancel{g\ Pb}} = 27\underline{7}.76\ J \quad \boxed{278\ J}$$

5. Calculate the enthalpy change in joules when 253.00 g of liquid water freezes?

$$\frac{253.0\underline{0}\ \cancel{g\ H_2O}}{} \times \frac{1\ \cancel{mol\ H_2O}}{18.01\underline{5}\ \cancel{g\ H_2O}} \times \frac{-\ 6.0\underline{2}\ \cancel{kJ}}{1\ \cancel{mol\ H_2O}} \times \frac{1000\ J}{1\ \cancel{kJ}} = -\ 84\underline{5}43.9\ J \quad \boxed{-\ 8.45 \times 10^4\ J}$$

(Since water is freezing instead of melting, the ΔH is negative ($\Delta H_{(sol)}$).)

6. What is the enthalpy of vaporization of a substance if it takes 34212 J to vaporize 25.0 g?

$$\frac{3421\underline{2}\ J}{25.\underline{0}\ g} = 13\underline{6}8.48\ J/g \quad \boxed{1370\ J/g}$$

7. How many kilocalories does it take to melt 12.9 g of sodium chloride if the heat of fusion is 28.16 kJ/mol?

$$\frac{12.\underline{9}\ \cancel{g\ NaCl}}{} \times \frac{1\ \cancel{mol\ NaCl}}{58.44\underline{3}\ \cancel{g\ NaCl}} \times \frac{28.1\underline{6}\ \cancel{kJ}}{1\ \cancel{mol\ NaCl}} \times \frac{1\ kcal}{4.18\underline{4}\ \cancel{kJ}} = 1.4\underline{8}55\ kcal \quad \boxed{1.49\ kcal}$$

8. How many kilojoules of heat are absorbed when 0.46 g of chloroethane (C_2H_5Cl, boiling point 12.3°C) vaporizes at its boiling point? ($\Delta H_{(vap)}$ = 26.4 kJ/mol)

$$\frac{0.4\underline{6}\ \cancel{g\ C_2H_5Cl}}{} \times \frac{1\ \cancel{mol\ C_2H_5Cl}}{64.51\underline{5}\ \cancel{g\ C_2H_5Cl}} \times \frac{26.\underline{4}\ \cancel{kJ}}{1\ \cancel{mol\ C_2H_5Cl}} = 0.1\underline{8}82\ kJ \quad \boxed{0.19\ kJ}$$

9. Given that benzoic acid has a molar mass of 122.1 g/mol and a 52.9 g sample of benzoic acid absorbs 7.83 kJ when it melts, calculate the molar enthalpy of fusion of benzoic acid.

$$\frac{7.7\underline{3}\ kJ}{52.\underline{9}\ \cancel{g\ BA}} \times \frac{122.\underline{1}\ \cancel{g\ BA}}{1\ mol\ BA} = 18.\underline{0}72\ kJ/mol \quad \boxed{18.1\ kJ/mol}$$

Answers: 1) 334 J/g 2) 540. cal/g 3) –113 kJ 4) 278 J 5) –8.45x10[4] J 6) 1370 J/g 7) 1.49 kcal 8) 0.19 kJ 9) 18.1 kJ/mol