

# 16 • Thermochemistry

## CHANGES IN STATES WORKSHEET

1. Write a chemical equation for the following changes (include "heat"). Indicate whether each is endothermic or exothermic.

(a)	The melting of ice. $\text{heat} + \text{H}_2\text{O}_{(s)} \rightarrow \text{H}_2\text{O}_{(l)}$	endo   <u>exo</u>
(b)	The condensation of steam. $\text{H}_2\text{O}_{(g)} \rightarrow \text{H}_2\text{O}_{(l)} + \text{heat}$	endo   <u>exo</u>
(c)	The vaporization of liquid water. $\text{heat} + \text{H}_2\text{O}_{(l)} \rightarrow \text{H}_2\text{O}_{(g)}$	<u>endo</u>   exo
(d)	The freezing of liquid water. $\text{H}_2\text{O}_{(l)} \rightarrow \text{H}_2\text{O}_{(s)} + \text{heat}$	endo   <u>exo</u>

2. For water,  $\Delta H_{\text{fus}} = 333 \text{ J/g}$ ,  $\Delta H_{\text{vap}} = 2260 \text{ J/g}$ .

(a)	Find the value for Q when 15.0 g water freezes.	VARIABLES:	WORK: $Q = m \Delta H_{\text{fus}}$ $15.0 \text{ g H}_2\text{O} \times \frac{333 \text{ J}}{\text{g}} = 4995 \text{ J released}$ or $-5.00 \times 10^3 \text{ J (s.f.)}$	ANSWER:
(b)	How many grams of water are converted to steam when 15,000 J of heat is absorbed?	VARIABLES:	WORK: $Q = m \Delta H_{\text{vap}}$ $15000 \text{ J} = m \left( \frac{2260 \text{ J}}{\text{g}} \right)$ $m = \frac{15000 \text{ J}}{2260 \text{ J/g}} = 6.637 \text{ g} = 6.6 \text{ g (s.f.)}$	ANSWER:
(c)	How much energy is released when 50.0 g of water vapor condenses into liquid?	VARIABLES:	WORK: $Q = m \Delta H_{\text{vap}}$ $= (50.0 \text{ g}) \left( \frac{2260 \text{ J}}{\text{g}} \right) = 113,000 \text{ J released}$	ANSWER: $-113 \text{ kJ}$
(d)	How much energy is absorbed when 1.80 moles of ice melts?	VARIABLES:	WORK: $1.80 \text{ mol H}_2\text{O} \times \frac{18.02 \text{ g H}_2\text{O}}{1 \text{ mol}} = 32.4 \text{ g}$ $Q = m \Delta H_{\text{fus}}$ $= 32.4 \text{ g} \left( \frac{333 \text{ J}}{\text{g}} \right) = 10789.2 \text{ J}$ or $10800 \text{ J (s.f.)}$	ANSWER:

3. What is the heat of fusion of aluminum, in cal/g, if 1423 cal of energy is required to melt a 15.0 gram sample?

VARIABLES:	WORK: $Q = m \Delta H_{\text{fus}}$ $1423 \text{ cal} = (15.0 \text{ g}) \Delta H_{\text{fus}}$ $\Delta H_{\text{fus}} = 1423 \text{ cal} / 15.0 \text{ g} = 94.86 \text{ cal/g}$	ANSWER: $94.9 \frac{\text{cal}}{\text{g}}$ (s.f.)
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4. How many grams of methanol can be vaporized if it is heated with 400 cal of energy?  $\Delta H_{\text{vap}} = 264 \text{ cal/g}$

VARIABLES:	WORK: $Q = m \Delta H_{\text{vap}}$ $400 \text{ cal} = m \left( \frac{264 \text{ cal}}{\text{g}} \right)$	ANSWER: $1.52 \text{ g}$
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$$m = \frac{400 \text{ cal}}{264 \frac{\text{cal}}{\text{g}}} = 1.5151 \text{ g}$$

5. The heat of vaporization,  $\Delta H_{\text{vap}}$ , of acetone,  $\text{C}_3\text{H}_6\text{O}$ , is 7480 cal/mol. (Pay attention to the units. Because it's given per "mole", our formula becomes  $Q = n \Delta H$ , where  $n$  is number of moles.)

(a) Calculate the number of moles if we have a 30.0 gram sample of acetone.

$$30.0 \text{ g} \times \frac{1 \text{ mol}}{58.12 \text{ g}} = 0.51617 \text{ mol}$$

$$\text{C}_3\text{H}_6\text{O} = 3(12.01) + 6(1.01) + 16 = 58.12 \text{ g}$$

(b) How much energy is required to vaporize the 30.0 gram sample of acetone?

VARIABLES:

WORK:

$$Q = n \Delta H_{\text{vap}}$$

ANSWER:

$$= (0.516 \text{ mol}) (7480 \frac{\text{cal}}{\text{mol}}) = 3862.97 \text{ cal} = 3860 \text{ cal (s.f.)}$$

6. The heat of fusion,  $\Delta H_{\text{fus}}$ , of lead is 1213 J/mol. How much energy is required to melt a 320 gram piece of lead?

VARIABLES:

WORK:

$$n = 320 \text{ g Pb} \times \frac{1 \text{ mol Pb}}{207.2 \text{ g}} = 1.5444 \text{ mol Pb}$$

$$Q = n \Delta H_{\text{fus}}$$

$$= (1.544 \text{ mol}) (1213 \frac{\text{J}}{\text{mol}})$$

$$= 1873.359 \text{ J}$$

ANSWER:

$$1900 \text{ J (s.f.)}$$

7. It takes 3000 J to melt a 20-g block of solid A, and 4500 J to melt a 20-g block of solid B. Which has a greater heat of fusion,  $\Delta H_{\text{fus}}$ ? Explain without using math.

Solid B has a greater heat of fusion. It resists change in phase more than A and requires more energy to melt.

8. The heats of vaporization for ethanol and water are 201 cal/g and 540 cal/g, respectively. If 2000 calories of heat are added to a sample of each substance, which substance will produce more vapor? Explain briefly.

Ethanol will produce more vapor.

Its  $\Delta H_{\text{vap}}$  is smaller, meaning it has less resistance to change than water.