

## 1. HEAT

## REVIEW AND PRACTICE 1

### Learning Goal

I can solve problems involving the transfer of thermal energy (heat).

### Summary

- Heat is the quantity of thermal energy transferred to/from a substance.
- Like all quantities of energy, heat is measured in joules (J).
- A positive heat value means that the substance gained thermal energy (energy was transferred *to* the substance).
- A negative heat value means that the substance lost thermal energy (energy was transferred *from* the substance).
- Heat can be calculated using the formula  $q = mc\Delta T$ .

$q$  is heat (quantity of heat transferred)

$m$  is mass of the substance

$c$  is the specific heat capacity of the substance

$\Delta T$  is the change in temperature of the substance ( $\Delta T = T_2 - T_1$ )

- The formula can be rearranged to calculate any of the variables depending on what data you have.

### Example Quantitative Problem

A pot contains 2.5 L of water at 20.3°C. Calculate the final temperature of the water when 187 kJ of thermal energy is transferred to the water by a heating coil.

#### SOLUTION

Given:  $V_{\text{H}_2\text{O}} = 2.5\text{L}$  ⇨ Because the density of water is 1g/mL, the mass of the water is 2500 g.

$T_1 = 20.3^\circ\text{C}$

$q = +187\text{kJ}$  ⇨ Positive value because the energy is *transferred to the water*.

$c_w = 4.18\text{J g}^{-1}\text{C}^{-1}$  ⇨ The specific heat capacity for water is known.

Required:  $T_2 = ?$

Analysis:  $q = mc\Delta T$

$$q = mc(T_2 - T_1)$$

$$\frac{q}{mc} = T_2 - T_1 \quad \text{⇨ Rearrange equations before entering values.}$$

$$\frac{q}{mc} + T_1 = T_2$$

$$T_2 = \frac{q}{mc} + T_1$$

Solution:

$$T_2 = \frac{+187\text{000 J}}{(2500\text{ g})(4.18\text{ J g}^{-1}\text{C}^{-1})} + \underline{20.3}^\circ\text{C}$$

⇨ Show unit analysis.

⇨ Significant figures are underlined.

$$= \underline{17.8947}\dots^\circ\text{C} + \underline{20.3}^\circ\text{C}$$

$$= \underline{38.1947}\dots^\circ\text{C}$$

Statement:

Therefore, the final temperature of the water is 38°C

#### Practice Problem 1

When 150 g of acetone cools from 63°C to 25°C, the acetone releases 12.3 kJ of thermal energy. Calculate the specific heat capacity of acetone.

(ANSWER 2.2 J g<sup>-1</sup>C<sup>-1</sup>)

## 2. ENTHALPY CHANGE

### Learning Goal

I can solve quantitative problems involving enthalpy changes.

### Summary

- Enthalpy change is the quantity of thermal energy released or absorbed by a chemical reaction.
- Like all quantities of energy, enthalpy change is measured in joules (J).
- A positive enthalpy change means that the reaction absorbs energy (endothermic reaction).
- A negative enthalpy change means that the reaction releases energy (exothermic reaction).
- Molar enthalpy change is the change in enthalpy per mole of substance.

$$\Delta H_x = \frac{\Delta H}{n}$$

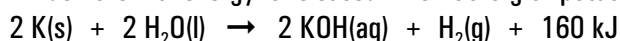
$\Delta H_x$  is the molar enthalpy change

$\Delta H$  is the total enthalpy change

$n$  is the amount of the substance causing the total enthalpy change

### Example Quantitative Problem

How much thermal energy is released when 60.0 g of potassium metal reacts according to the following equation?



#### SOLUTION

1. Convert the energy term in the chemical equation to a molar enthalpy change.

$$n_K = 2 \text{ mol} \quad \Leftrightarrow \text{From the chemical equation (2 K(s) + ...)}$$

$$\Delta H = -160 \text{ kJ} \quad \Leftrightarrow \text{From the chemical equation; negative because the energy is released}$$

$$\Delta H_x = \frac{\Delta H}{n} = \frac{-160 \text{ kJ}}{2 \text{ mol}} = -80 \text{ kJ/mol} \quad \Leftrightarrow \text{with respect to potassium}$$

\*The 2 mol from the chemical equation is not a measured value. The 2 is an exact number, and does not affect significant figures in the calculation.

2. Calculate the amount (in moles) of potassium reacting.

$$n_K = \frac{m_K}{M_K} = \frac{60.0 \text{ g}}{39.10 \text{ g mol}^{-1}} = 1.5345... \text{ mol} \quad \Leftrightarrow \text{Show unit analysis.}$$

3. Calculate the enthalpy change caused by this amount of potassium.

$$\Delta H = n \Delta H_x = (1.5345... \text{ mol})(-80 \text{ kJ/mol}) = -122.762... \text{ kJ} \quad \Leftrightarrow \text{Show unit analysis.}$$

Therefore, the thermal energy released is  $1.2 \times 10^2$  kJ.  $\Leftrightarrow$  The term "released" replaces the negative sign.

### Practice Problem 2

What mass of butane must burn to release 6500 kJ of thermal energy?



(ANSWER 0.13 kg)

### 3. CALORIMETRY

#### Learning Goal

I can analyse calorimetry data to find the molar enthalpy change for a chemical reaction or physical change.

#### Summary

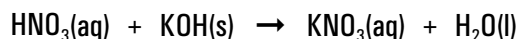
- Calorimetry is a technique for measuring the enthalpy change for a reaction.
- The calorimeter is an isolated system (not perfectly but close enough to assume in the calculations).
- Therefore, the thermal energy lost by the chemical reaction is equal to the thermal energy gained by the contents of the calorimeter (or vice versa).

#### Example Quantitative Problem

Refer to the solutions to the practice questions in Lesson 4: Calorimetry.

#### Practice Problem 3

A chemistry student is experimentally determining the molar enthalpy change with respect to potassium hydroxide for the following neutralization reaction.



She adds solid potassium hydroxide to nitric acid solution in a polystyrene calorimeter, and collects the following data.

mass of potassium hydroxide put in calorimeter = 5.16 g

volume of nitric acid put in calorimeter = 198.3 mL

initial temperature of the solution = 21.0 °C

final temperature of the solution = 28.1 °C

Complete the analysis. Clearly present all calculations including unit analysis, and state any assumptions that you make. Write a conclusion.

(ANSWER -64 kJ/mol KOH)