Objective 8: Energy and heat 1: predict heat in a physical heat transfer. Apply heat equations ($q = m\Delta T$, heat gained = heat lost)

Quiz Practice problems:

Key ideas:

Heat is the energy transferred between two objects due to a difference in temperature.

Three factors determine the amount of heat transferred: mass, specific heat, and temperature.

Skills: Use heat equations to determine heat transferred.

Heat gained = - heat lost.

Identify what is gaining heat and what is losing heat.

$q = m\ s\ \Delta T$ where m = mass in g, s = specific heat in J/g °C, and $\Delta T = T_{final} - T_{initial}$ = difference in temperature.

1. a. If two objects at the same temperature touch each other, is heat transferred?

b. You shake your lab partner's hand. Your hand is warmer than your lab partner's. Which hand loses heat?

c. Specific heat is the amount of energy required to raise 1 g of a substance 1°C. The specific heat of water is 4.18 J/g °C. The specific heat of iron is 0.44 J/g °C. You have 100 g of water at 100°C and 100 g of iron at 100°C. Each object is placed on a table at 25°C. Which object cools faster?

Answers:

a. No heat is transferred between the two objects because each object is the same temperature – there is no difference in temperature.

b. warm hand loses heat to cold hand. Cold hand gains heat from warm hand.

c. The substance with the lower specific heat, iron in this case, cools faster. The iron only has to lose 0.44 J per g to lower its temperature 1°C whereas water has to lose a lot more energy, 4.18 J per g, to lower its temperature 1°C.

2. a. 1 cup (240 ml) of water is heated from 25°C to 75°C. Calculate q. (Answer: approximately 50,000 J)

b. 1 cup (240 ml) ethanol (specific heat = 2.46 J/g °C) is heated from 25°C to 75°C. Calculate q.

c. Why does water require more heat than ethanol?

Answers:

a. $q = m\ s\ \Delta T$ = 240 g (4.18 J/g °C)(75°C - 25°C) = 50160 J. Water gains heat in raise T.

Use density of water to convert ml of water to g of water: 240 ml water (1 g water/1 ml water) = 240 g water

b. $q = m\ s\ \Delta T$ = 189.6 g (2.46 J/g °C)(75°C - 25°C) = 23321 J. Ethanol gains heat in raise T.

Use density of ethanol to convert ml of ethanol to g of ethanol: 240 ml ethanol (0.79 g ethanol /1 ml ethanol) = 240 g ethanol

c. Water requires more heat to raise the same volume the same ΔT because it has a higher specific heat and higher mass due to its higher density.

4.18 J/g °C means 4.18 J of heat is required to raise 1 g of water 1°C.

2.46 J/g °C means 2.46 J of heat is required to raise 1 g of ethanol 1°C.

3. Add 50 ml of water at 25°C to 50 ml of water at 100°C.

a. heat gained by _____ water = - heat lost by ____ water

$m\ s\ (T_f - T_i) = -\ m\ s\ (T_f - T_i)$

b. What quantities are you given?

c. What quantity is not known?

d. Fill in equation. Solve for unknown.

Answers:

a. heat gained by 25°C (cold) water = - heat lost by 100°C (hot) water

b. Given: mass of 25°C (cold) water, mass of 100°C (hot) water, specific heat of water, T_i of 25°C (cold) water, T_i of 100°C (hot) water.

Use density of water to convert ml of water to g of water: 50 ml water (1 g water/1 ml water) = 50 g water

c. T_f is not known. T_f of the cold water and T_f of the hot water are the same.

d. $m_{cold\ water}\ s_{cold\ water}\ (T_f - T_{i\ cold\ water}) = -\ m_{hot\ water}\ s_{hot\ water}\ (T_f - T_{i\ hot\ water})$

(50 g)(4.18 J/g °C)(T_f - 25°C) = - (50 g)(4.18 J/g °C)(T_f - 100°C)

T_f = 62.5°C

4. a. 200 ml of water at 25°C is added to 850 ml of water at 100°C. Calculate T_f.

b. Your coffee is way too hot. You have 200 ml of coffee (assume it is water) at 150°F (= 65.5°C). How much 25°C water should you add to cool the coffee to 110°F (= 43.3°C)? (Hint: What equation should you use?)

Answers:

a. Use density of water to convert ml of water to g of water: 200 ml water (1 g water/1 ml water) = 200 g water

$m_{cold\ water}\ s_{cold\ water}\ (T_f - T_{i\ cold\ water}) = -\ m_{hot\ water}\ s_{hot\ water}\ (T_f - T_{i\ hot\ water})$

(200 g)(4.18 J/g °C)(T_f - 25°C) = - (850 g)(4.18 J/g °C)(T_f - 100°C)

T_f = 85.7°C

b. Assume coffee is water.
Use density of water to convert ml of water to g of water.
Use $m_{\text{cold water}}\, s_{\text{cold water}}\, (T_f - T_{i\,\text{cold water}}) = -\, m_{\text{hot water}}\, s_{\text{hot water}}\, (T_f - T_{i\,\text{hot water}})$
(x g)(4.18 J/g °C)(43.3°C - 25°C) = - (200 g)(4.18 J/g °C)(43.3°C - 65.5°C)
x = 243 g of 25°C water will cool 200 ml of coffee 150°F (= 65.5°C) to 110°F (= 43.3°C).

5. 20.0 g of a metal at 100°C is added to 60 ml of water at 25°C. T_f of the water and metal is 27.5°C.
a. Calculate the specific heat of the metal. (Hint: What equation should you use?)
b. What is the identity of the metal?
c. If you want to see a bigger temperature change in the metal, should you use more water or less water? Give reasons.
Answers:
a. Use $m_{\text{cold water}}\, s_{\text{cold water}}\, (T_f - T_{i\,\text{cold water}}) = -\, m_{\text{hot metal}}\, s_{\text{hot metal}}\, (T_f - T_{i\,\text{hot metal}})$
Use density of water to convert ml of water to g of water.
(60 g)(4.18 J/g °C)(27.5°C - 25°C) = - (20.0 g)(x J/g °C)(27.5°C - 100°C)
x = 0.43 J/g °C
b. s of Fe = 0.444 J/g °C, s of Ni = 0.44 J/g °C so the metal is Fe or Ni.
c. Use less water. From equation, $m_{\text{cold water}}\, s_{\text{cold water}}\, (T_f - T_{i\,\text{cold water}}) = -\, m_{\text{hot metal}}\, s_{\text{hot metal}}\, (T_f - T_{i\,\text{hot metal}})$, if $m_{\text{cold water}}$ is smaller, the heat gained by the cold water is smaller, which means the heat lost by the metal is smaller so T_f increases.

6. A rock and gold cup lie in the middle of the Mojave desert in the middle of a hot, sunny day. Which object contains more heat? Give reasons.
Answers:
Neither object contains heat. Heat is the energy transferred between two objects due to a difference in temperature. Heat is not contained in an object (heat is a path function or non-thermodynamic quantity, which means it is not a property of a substance). The energy contained in a substance that is converted to heat is called enthalpy. Enthalpy is a state function or thermodynamic quantity, which means it is a property of a substance.