CHAPTER 12 ENERGY FROM HYDROCARBONS

Try This Activity : Hot and Cold

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- The white solid mixed and dissolved in the water. As the solid dissolved, the bottom of the plastic bag felt quite hot compared with the initial water.
- The two white solids did not appear to change when added together in one corner of the bag. When mixed with the water, there was an immediate release of gas bubbles that inflated the bag. The bottom of the bag felt colder than the initial water and the solid mixture appeared to dissolve.

(a) The calcium chloride mixture felt hot. The heat must have come from the dissolving of the calcium chloride in water.
(b) There was no apparent change.
(c) A gas was produced and the mixture got colder. Because there was no apparent change when the dry solids mixed and both solids are soluble in water, it appears that water dissolved the solids, which allowed the reaction to occur. (Another possibility is that one or both of the solids reacted with the water. How would you test this?)
(d) When something feels cold, its temperature is likely lower than your skin temperature. "Cold" is a description of a sensation and is not a substance or thing. When something feels cold, heat is being transferred from your skin to the object.
(e) endothermic: calcium chloride and water
exothermic: citric acid, baking soda, and water

12.1 CLASSIFYING ENERGY CHANGES

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Understanding Concepts

1. Essential energy-using devices might include home furnaces and the family automobile. Convenient devices might be things like toasters and light bulbs. Nonessential devices might be things like electric can openers and electric toothbrushes.
2. (a) Furnace — heat energy
Automobile — mechanical energy
Toaster — heat energy
Light bulb — light energy
Can opener — mechanical energy
Electric toothbrush — mechanical energy

(b) Furnace — chemical — fossil fuels
Automobile — chemical — fossil fuels
Toaster — electrical devices may have any source,
Light bulb and the electrical energy may come
Can opener from any of the resources listed.
Electric toothbrush

Reflecting

3. Energy-conserving strategies suggested might include: turning thermostats down at night, lowering the heat of water heaters, keeping auto tires fully inflated, buying more fuel-efficient cars and furnaces, car-pooling, caulking windows, and many others.

Try This Activity : Energy Inventory

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Energy Device/Use	Type of Energy	Natural Resource
lights — inside & outside	electrical	fossil fuels, uranium, and/or water
appliances — kitchen, entertainment, cleaning, personal care	electrical	fossil fuels, uranium, and/or water
hot-water tank	electrical or chemical (natural gas)	fossil fuels, uranium, and/or water
home heating (furnace/heaters)	electrical or chemical (fuel oil or natural gas)	fossil fuels, uranium, and/or water
lawn mower	chemical (gasoline)	fossil fuels
barbecue	chemical (propane)	fossil fuels

(a) Most of the total energy use seems to depend on fossil fuels. A rough estimate would be 65%, if we assume electrical and chemical sources are approximately equal in quantity of energy used and 30% of the electrical originates from fossil fuels (and the rest from other sources such as hydro and nuclear power plants).

(b) Risks: pollution, global warming, ozone depletion, depleting a nonrenewable resource
Benefits: relatively inexpensive, convenient, plenty of fossil fuels in Canada, provides economic benefit through royalties and jobs

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Understanding Concepts

4. (a) If we assume the physical state of the samples and the quantity of heat transferred are constant, doubling the mass should halve the temperature increase.
   (b) If we assume the physical state and mass of the samples are constant, doubling the quantity of heat transferred should double the temperature increase.
   (c) If we assume the physical state and mass of the samples are constant, doubling the specific heat capacity should halve the temperature increase.

5. $q = ?$

$m = 1.50\ \cancel{\text{L}} \times 1\ \text{kg}/\cancel{\text{L}} = 1.50\ \text{kg}$

$c = 4.18\ \text{J/(g} \cdot {}^\circ\text{C)}$

$\Delta t = \left|98.7^\circ\text{C} - 18.0^\circ\text{C}\right| = 80.7^\circ\text{C}$

$$\begin{aligned} q &= mc\Delta t \\ &= 1.50\ \text{k}\cancel{\text{g}} \times \frac{4.18\ \text{J}}{\cancel{\text{g}} \cdot \cancel{{}^\circ\text{C}}} \times 80.7\cancel{{}^\circ\text{C}} \\ q &= 506\ \text{kJ} \end{aligned}$$

The quantity of heat transferred to the water is 506 kJ.

6. $q = ?$

$m = 100\ \text{kg}$

$c = 2.01\ \text{J/(g} \cdot {}^\circ\text{C)}$

$\Delta t = \left|210^\circ\text{C} - 100^\circ\text{C}\right| = 110^\circ\text{C}$

$$\begin{aligned} q &= mc\Delta t \\ &= 100\ \text{k}\cancel{\text{g}} \times \frac{2.01\ \text{J}}{\cancel{\text{g}} \cdot \cancel{{}^\circ\text{C}}} \times 110\cancel{{}^\circ\text{C}} \\ q &= 2.21 \times 10^4\ \text{kJ} = 22.1\ \text{MJ} \end{aligned}$$

The quantity of heat transferred to the steam is 22.1 MJ.

7. $q = ?$

$m = 2.5 \text{ kg}$

$c = 0.86 \text{ J/(g} \cdot \text{°C)}$

$\Delta t = |15\text{°C} - 350\text{°C}| = 335\text{°C}$

$$q = mc\Delta t$$
$$= 2.5 \text{ k}\cancel{\text{g}} \times \frac{0.86 \text{ J}}{\cancel{\text{g}} \cdot \cancel{\text{°C}}} \times 335\cancel{\text{°C}}$$
$$q = 7.2 \times 10^2 \text{ kJ} = 0.72 \text{ MJ}$$

The quantity of heat transferred from the rock is 0.72 MJ.

8. $q = ?$

$m = 1.20 \text{ kg}$

$c = 4.18 \text{ J/(g} \cdot \text{°C)}$

$\Delta t = |65.0\text{°C} - 12.0\text{°C}| = 53.0\text{°C}$

$$q = mc\Delta t$$
$$= 1.20 \text{ k}\cancel{\text{g}} \times \frac{4.18 \text{ J}}{\cancel{\text{g}} \cdot \cancel{\text{°C}}} \times 53.0\cancel{\text{°C}}$$
$$q = 266 \text{ kJ}$$

The quantity of heat transferred to the water is 266 kJ.

$q = ?$

$m = 450 \text{ g}$

$c = 0.510 \text{ J/(g} \cdot \text{°C)}$

$\Delta t = |65.0\text{°C} - 12.0\text{°C}| = 53.0\text{°C}$

$$q = mc\Delta t$$
$$= 450 \cancel{\text{g}} \times \frac{0.510 \text{ J}}{\cancel{\text{g}} \cdot \cancel{\text{°C}}} \times 53.0\cancel{\text{°C}}$$
$$q = 1.22 \times 10^4 \text{ J} = 12.2 \text{ kJ}$$

The quantity of heat transferred to the pot is 12.2 kJ.

The total quantity of heat entering the stainless steel pot and the water together is (266 + 12.2) kJ = 278 kJ.

9. $q = 1.8 \text{ MJ}$

$m = 0.200 \text{ m}^3 \times 0.917 \text{ Mg/m}^3 = 0.183 \text{ Mg}$

$c = 2.01 \text{ J/(g} \cdot \text{°C)}$

$\Delta t = ?$

$$q = mc\Delta t$$
$$\Delta t = \frac{q}{mc}$$
$$= \frac{1.8 \cancel{\text{MJ}}}{0.183 \cancel{\text{Mg}} \times \frac{2.01 \cancel{\text{J}}}{\cancel{\text{g}} \cdot \text{°C}}}$$
$$\Delta t = 4.9\text{°C}$$

The temperature increase of the ice is 4.9°C.

If we assume an initial temperature for the ice of –15°C, as given in Sample Problem 2 (page 569), the increase in temperature will not melt the ice.

Applying Inquiry Skills

10. **Experimental Design**

A submersible electric heating element is used to transfer known quantities of heat to known masses (independent variables) of water and of oil. The temperature rise (dependent variable) of the liquids is recorded for each trial, and the specific heat capacity calculated.

11. **Evaluation**

The design of this experiment is judged to be adequate because the evidence obtained allowed the question to be answered easily and fully, and was consistent, with only very small variations (errors). There are no flaws in the design, and no improvements are suggested.

Making Connections

12. Typical answers might include:
For ice, the cooling effect on a fruit drink might be calculated
For water, the heat transfer from you to the water during a swim might be calculated.
For steam, the severity of a scald from a kettle could be calculated as an amount of heat transferred.

13. Answers will vary with home data. A typical answer might be:

$q = ?$

$m = 150\ \cancel{\text{L}} \times 1\ \text{kg}/\cancel{\text{L}} = 150\ \text{kg}$

$c = 4.18\ \text{J/(g} \cdot \text{°C)}$

$\Delta t = \left| 74\text{°C} - 15\text{°C} \right| = 59\text{°C}$

$$\begin{aligned} q &= mc\Delta t \\ &= 150\ \text{k}\cancel{\text{g}} \times \frac{4.18\ \text{J}}{\cancel{\text{g}} \cdot \cancel{\text{°C}}} \times 59\cancel{\text{°C}} \\ q &= 3.7 \times 10^4\ \text{kJ} = 37\ \text{MJ} \end{aligned}$$

The quantity of heat transferred to warm a tankful of water is 35 MJ.

Reflecting

14. The term “hot” is used commonly to refer to objects with a higher temperature than the human skin surface — a very subjective definition that most students will agree was their initial concept. After studying this chapter, students will usually try to discuss the word in terms of the transfer of heat — which depends on the specific heat capacity and mass, as well as the temperature.
15. Heat transfers from your hands to the snow, creating the nervous system response you call “cold.”

PRACTICE

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Understanding Concepts

16. (a) Temperature, t, is related to the average value of the kinetic energy, E_k, of the particles in a sample.
    (b) Heat transferred, q, is related to the change in the total value of the kinetic energy, ΔE_k, of the particles in a sample.
17. (a) The average kinetic energy increases.
    (b) The average kinetic energy decreases.
    (c) The average kinetic energy increases.
    (d) The average kinetic energy decreases.
18. (a) The change in the pasta is endothermic.
    (b) The change in the methane is exothermic.
19. In an endothermic chemical change, the higher average energy particles in the surroundings collide with, and transfer some energy to, the lower average energy particles in the chemical system. In an exothermic chemical change, the higher average energy particles in the chemical system collide with, and transfer some energy to, the lower average energy particles in the surroundings.

SECTION 12.1 QUESTIONS

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Understanding Concepts

1. Specific heat is heat transferred per unit of mass, while specific heat capacity is heat transferred per unit of mass, per degree of temperature change.
2. The expression $q = mc\Delta t$ translates to an explanation of heat relationships. The amount of heat transferred depends directly on the mass of substance, the temperature change, and the specific heat capacity — which is a value for the heat transferred per unit of mass, per degree of temperature change, for a given substance.
3. q = ?

   $m = 1.1\ \cancel{\text{L}} \times 1\ \text{kg}/\cancel{\text{L}} = 1.1\ \text{kg}$

   $c = 4.18\ \text{J/(g} \cdot {}^\circ\text{C)}$

   $\Delta t = |98^\circ\text{C} - 12^\circ\text{C}| = 86^\circ\text{C}$

   $$\begin{aligned} q &= mc\Delta t \\ &= 1.1\ \text{k}\cancel{\text{g}} \times \frac{4.18\ \text{J}}{\cancel{\text{g}} \cdot \cancel{{}^\circ\text{C}}} \times 86\cancel{{}^\circ\text{C}} \\ q &= 395\ \text{kJ} \end{aligned}$$

   The quantity of heat transferred to the water is 395 kJ.
4. q = 295 kJ

   m = ?

   $c = 4.18\ \text{J/(g} \cdot {}^\circ\text{C)}$

   $\Delta t = |78^\circ\text{C} - 5^\circ\text{C}| = 73^\circ\text{C}$

   $$\begin{aligned} q &= mc\Delta t \\ m &= \frac{q}{c\Delta t} \\ &= \frac{295\ \text{k}\cancel{\text{J}}}{\dfrac{4.18\ \cancel{\text{J}}}{\text{g} \cdot \cancel{{}^\circ\text{C}}} \times 73\cancel{{}^\circ\text{C}}} \\ m &= 0.967\ \text{kg} = 967\ \text{g} \end{aligned}$$

   The mass of water that can be warmed is 967 g.
5. (a) The lower specific heat capacity of alcohol means an equal mass would only work about half as well as water. The same temperature increase takes only half as much heat transfer to alcohol as for water — so there would be only half as much stored energy to release later.

   (b) For the same amount of heat to cause the same temperature change, the mass of alcohol would have to be about twice the mass of water.

12.2 CALORIMETRY

PRACTICE

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Understanding Concepts

1. For simple calorimeters we make assumptions that negligible heat transfers from the contents to the environment, that negligible heat transfers from the contents to the calorimeter materials, and that the specific heat capacity and density of the contents are negligibly different from water.