CHEM1612 Worksheet 1: Introduction to Thermodynamics

Model 1: Calorimetry

Heat is not the same thing as *temperature*, even though in common usage these concepts are often used interchangeable. *Heat* is the *energy transferred* from one object to another due to a difference in their temperature. Heat, therefore, has units of energy (joules, J). An object at a higher temperature will transfer energy to one at a lower temperature until they reach *thermal equilibrium* – until they are at the same temperature.

The amount of heat gained (to raise the temperature) or lost (to lower the temperature) by an object can be quantified with the following equations:

(1) $q = mc\Delta T$ or (2) $q = nC\Delta T$

where q is the heat change (in J), m is the mass (in g), n is the number of moles (in mol), c is the specific heat capacity (in J g^{-1} K^{-1}) and C is the molar heat capacity (J mol^{-1} K^{-1}).

The change in temperature, ΔT, is always:

$\Delta T = T_{\text{final}} - T_{\text{initial}}$

Hence, if the temperature increases, ΔT is positive and, if the temperature decreases, ΔT is negative.

The two equations (1) and (2) will give the same value for q as long as the *specific heat capacity* is used when you know the mass and the *molar heat capacity* is used when you know the number of moles.

The specific and molar heat capacities are a measure of how much energy is needed to raise the temperature of 1 g or 1 mol, respectively, of an object by 1 K. Every object has a different heat capacity: some substances, like metals, are easier to heat than others, like rocks.

Critical thinking questions

1. Assuming no chemical reaction is occurring, under what circumstances would you get a negative value for the heat, q?

2. Provide an equation for converting between the specific heat capacity, c, and the molar heat capacity, C. (*Hint*: use the relationship between the number of moles and the mass of a substance).

3. If the temperature of a substance increases from 25 °C to 35 °C, what is ΔT (in Kelvin)?

4. Given your answer to Q3, explain to your group whether it is necessary to convert temperatures to Kelvin when working out ΔT.

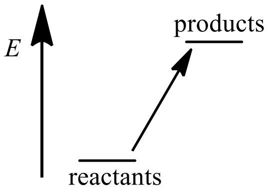
5. The specific heat capacity of olive oil is 2.0 J g^{-1} K^{-1}. How much energy has to be transferred to 2.0 g of olive oil in a saucepan to heat it from room temperature to 130 °C? Assume that the room is at 25 °C.

6. The specific heat capacity of water is 4.18 J g^{-1} K^{-1}. Is it easier or harder to heat water or olive oil?

7. The molar heat capacity of gold is 25.413 J mol^{-1} K^{-1}. A necklace that weighs 1.2 g requires 0.426 J of energy to heat by 2.00 K. Is the necklace pure gold? (*Hint*: you will first need to either convert the molar heat capacity to the specific heat capacity using the equation you worked out in Q2 or convert the mass into the moles).

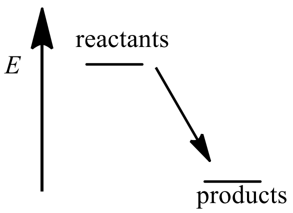
Model 2: Energy

When a physical or chemical change occurs in a system, energy is either absorbed or released. Energy is required to break chemical bonds, and conversely, energy is released when bonds are made. Usually, a chemical reaction involves *both* breaking *and* making bonds so energy can either be released or absorbed, depending on whether the bonds that are made are stronger or weaker than the bonds broken. The energy change in a chemical reaction often leads to a change in *thermal energy*: heat.



If the products are *less* stable (*higher* in energy) than the reactants, the reaction involves an increase in the energy.

This energy must be supplied and so the reaction absorbs energy from the surroundings making it feel colder.



If the products are *more* stable (*lower* in energy) than the reactants, the reaction involves a decrease in the energy.

This energy is released to the surroundings making it feel hotter.

Critical thinking questions

1. Which of the two figures above corresponds to the following reactions?

   (a) reactants → products + heat   (b) reactants + heat → products

2. If *ex* is the Greek prefix for *out* and *endo* is the Greek prefix for *in*, which of the above reactions is exothermic and which is endothermic? What do you think *thermo* means?

3. Will a beaker containing an endothermic reaction get colder or hotter?

The amount of energy absorbed or released by a reaction at constant pressure is called the *enthalpy of reaction*, ΔH. When energy, as heat, is *absorbed* in a reaction, ΔH is positive. This occurs when the bonds made in the products are weaker than those broken in the reactants.

4. If heat is released in a reaction, is ΔH positive or negative?

5. If heat is released in a reaction, are the bonds stronger or weaker in the products than in the reactants?

6. Is ΔH positive or negative for the two types of reaction:

   (a) exothermic   (b) endothermic

Marks 4

- A mass of 1.250 g of benzoic acid ($C_7H_6O_2$) underwent combustion in a bomb calorimeter. If the heat capacity of the calorimeter was 10.134 kJ K^{-1} and the heat of combustion of benzoic acid is –3226 kJ mol^{-1}, what is the change in internal energy during this reaction?

Answer:

Calculate the temperature change that should have occurred in the apparatus.

Answer:

Marks 2

- The specific heat capacity of water is 4.18 J g^{-1} K^{-1} and the specific heat capacity of copper is 0.39 J g^{-1} K^{-1}. If the same amount of energy were applied to a 1.0 mol sample of each substance, both initially at 25 °C, which substance would get hotter? Show all working.

Answer:

Marks
4

- A 150.0 g block of iron metal is cooled by placing it in an insulated container with a 50.0 g block of ice at 0.0 °C. The ice melts, and when the system comes to equilibrium the temperature of the water is 78.0 °C. What was the original temperature (in °C) of the iron?

Data: The specific heat capacity of liquid water is 4.184 J K^{-1} g^{-1}.
The specific heat capacity of solid iron is 0.450 J K^{-1} g^{-1}.
The molar enthalpy of fusion of ice (water) is 6.007 kJ mol^{-1}.

Answer:

Key to success: practice further by completing this week's tutorial homework