CHEM1001 Worksheet 9: Introduction to Thermodynamics

Model 1: Calorimetry

Heat is not the same thing as *temperature*, even though in common usage these concepts are often used interchangeably. *Heat* is the *transfer of energy* 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. A fridge does not cool food down: food warms up the fridge!

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 you use 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. Under what circumstances would you get a negative value for the heat change, 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. 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.

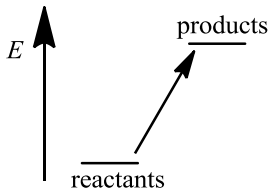
4. The specific heat capacity of water is 4.18 J g^{-1} K^{-1}. Is it easier or harder to heat water or olive oil?

5. 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).

6. Wood has a specific heat capacity of ca 1.7 J g^{-1} K^{-1}. Explain why gold (and other metals) feel cold to the touch compared to wood.

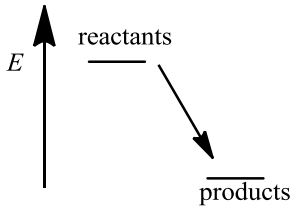
Model 2: Energy

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 reactants are *more* stable (*lower* in energy) than the products, the reaction involves an increase in the energy.

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



If the reactants are *less* stable (*higher* in energy) than the products, 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 adsorbed 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