Reactivity 1

What drives chemical reactions?

DP Chemistry

Chemistry Guide Statements

Skills in the study of chemistry			
Structure **Structure refers to the nature of matter from simple to more complex forms**		**Reactivity** **Reactivity refers to how and why chemical reactions occur**	
Structure determines reactivity, which in turn transforms structure			
Structure 1. **Models of the particulate nature of matter**	Structure 1.1—Introduction to the particulate nature of matter	**Reactivity 1.** **What drives chemical reactions?**	Reactivity 1.1—Measuring enthalpy changes
	Structure 1.2—The nuclear atom		Reactivity 1.2—Energy cycles in reactions
	Structure 1.3—Electron configurations		
	Structure 1.4—Counting particles by mass: The mole		Reactivity 1.3—Energy from fuels
	Structure 1.5—Ideal gases		Reactivity 1.4—Entropy and spontaneity (Additional higher level)

Reactivity 1.1—Measuring enthalpy changes 1.1.1 – 1.1.3

Guiding question: *What can be deduced from the temperature change that accompanies chemical or physical change?*

Reactivity 1.1.1—Chemical reactions involve a transfer of energy between the system and the surroundings, while total energy is conserved. Understand the difference between heat and temperature.	
	Structure 1.1—What is the relationship between temperature and kinetic energy of particles?

Reactivity 1.1.2—Reactions are described as endothermic or exothermic, depending on the direction of energy transfer between the system and the surroundings. Understand the temperature change (decrease or increase) that accompanies endothermic and exothermic reactions, respectively.	
	Tool 1, Inquiry 2—What observations would you expect to make during an endothermic and an exothermic reaction?

Reactivity 1.1.3—The relative stability of reactants and products determines whether reactions are endothermic or exothermic. Sketch and interpret energy profiles for endothermic and exothermic reactions.	
Axes for energy profiles should be labelled as reaction coordinate (x), potential energy (y).	Structure 2.2—Most combustion reactions are exothermic; how does the bonding in N_2 explain the fact that its combustion is endothermic?

Reactivity 1.1—Measuring enthalpy changes 1.1.1

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Chemical reactions involve heat transfers

R.1.1.1 **Lesson Objective**: Explain the trends in the properties of elements down a group and across a period

Do Now

 **10 mins**

Think-Pair-Share

Step 1: Think

Individually reflect on the following questions for 2 minutes. Write down your thoughts and ideas.

- What are the key differences between heat and temperature?
- How do open and closed systems affect heat retention in different scenarios?
- In what ways do enthalpy and energy conservation play a role in chemical reactions?

Step 2: Pair

Find a partner and share your thoughts. Discuss your responses to the questions for about 3 minutes. Listen to each other's perspectives and consider how your ideas might complement or challenge each other.

Step 3: Share

Come back to the larger group and share key insights from your discussions. Each pair should summarize one or two main points or questions that emerged during your conversation.

R.1.1.1

Lesson Objective: Understand the difference between heat and temperature

Heat vs. Temperature

What is heat?

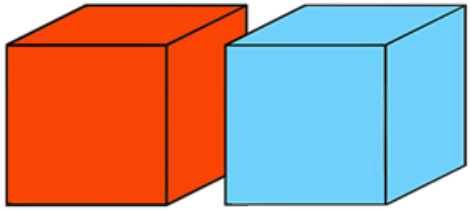
Heat, q, is a form of energy that is transferred from a warmer body to a cooler body, as a result of the temperature gradient.

Heat, as a flow of energy, has the units joules (J) or kilojoules (kJ).

When two objects are touching heat will flow from the object with the higher temperature to the object with the lower temperature.

- Heat is sometimes referred to as thermal energy. It can be transferred by the processes of conduction, convection and radiation.

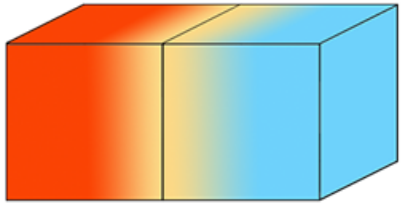
1. Not Touching - No Conduction



Initial temperature gradient:

- Two cubes are side by side.
- The left cube is colored red, representing a high temperature.
- The right cube is colored blue, representing a low temperature.

2. Conduction begins:
heat transfers to colder object

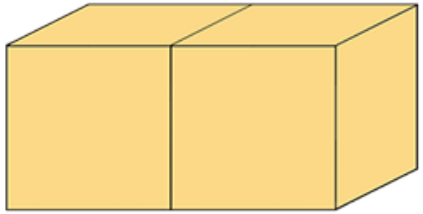


https://astro-asia.com/thermal-conduction.html

Heat conduction over time:

- The cubes begin to merge.
- The left cube remains red.
- The right cube remains blue.
- The area between the cubes shows a gradient from red to blue, indicating heat transfer from the hot cube to the cold cube.

3.Conduction completed:
Two objects are in equilibrium



Final temperature equilibrium:

- The cubes have merged into a single larger cube.
- The entire larger cube is uniformly colored a light yellow, representing an even temperature distribution after equilibrium is reached.

Lesson Objective: Understand the difference between heat and temperature

Heat vs. Temperature

What is temperature?

Temperature is a measure of the average kinetic energy of particles.

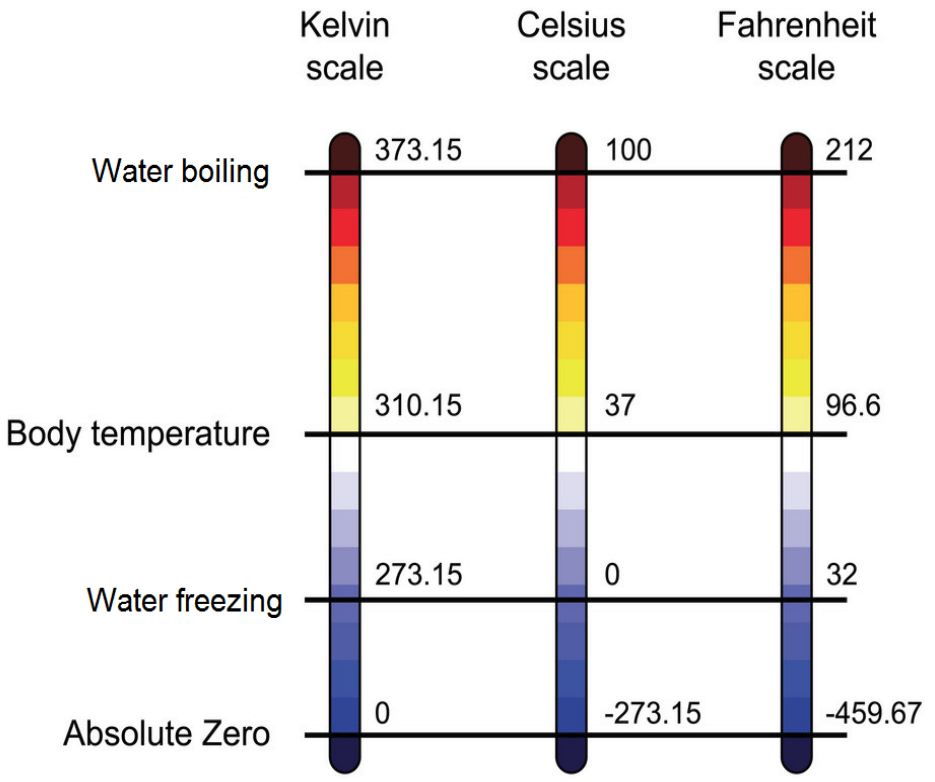
Temperature T, is an example of a state function. For a state function, any change in value is independent of the pathway between the initial and final measurements.

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

*The average kinetic energy of the particles in a substance is **proportional** to temperature measured in **kelvin**.*

*To convert from degrees Celsius (°C) to kelvin (K): **K = °C + 273.15***

***Absolute zero** occurs at 0 K. At this temperature all movement stops so the average kinetic energy of particles is zero.*



R.1.1.1

Lesson Objective: Understand the difference between heat and temperature

Group Task

GUIDING QUESTION:

Which system was better at retaining heat in the specified conditions?

In a chemistry lab, students are investigating the concept of open and closed systems. The students are provided with two identical flasks, one open and the other closed. Each flask is filled with a specific amount of water and a thermometer is placed in each flask to measure the temperature. The students are tasked with heating both flasks using Bunsen burners for a fixed amount of time and then recording the temperature changes.

Type of flask/system	Initial temperature of water	Final temperature of water
Open	25	45
Closed	25	35

Use this scenario to analyze and interpret the data provided in the table. Write a clear claim, support it with evidence from the data, and provide reasoning to explain the connection.

Closed, because lower change in temperature, so less heat moved around.

R.1.1.1

Lesson Objective: Understand the difference between heat and temperature

Group Task

GUIDING QUESTION:

Which system was better at retaining heat in the specified conditions?

Claim

The closed system retained heat better than the open system.

Evidence

The data collected shows that the final water temperature in the closed system was 35°C, which is lower than the final temperature of 45°C in the open system. This indicates that the closed system was able to retain more heat compared to the open system.

Reasoning

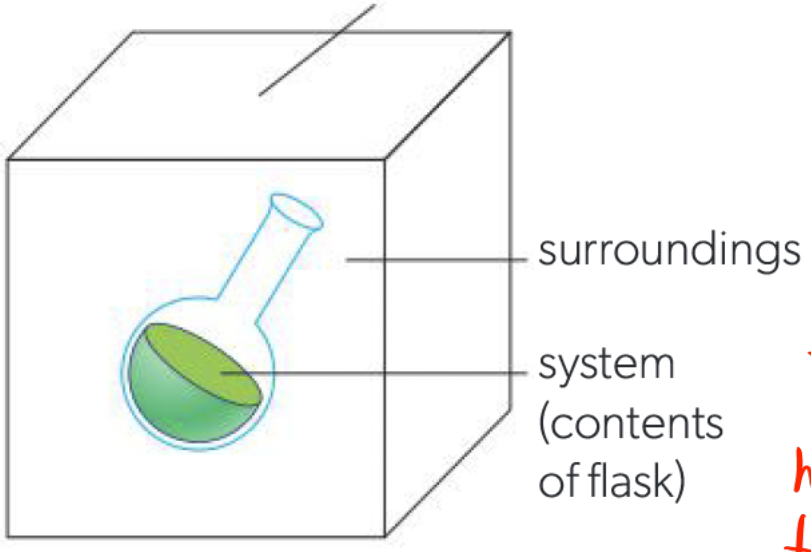
In a closed system, heat exchange with the surroundings is limited, leading to better heat retention. The closed container prevented heat loss to the surroundings more effectively than the open container, resulting in a lower final temperature for the closed system. This demonstrates the difference in how open and closed systems interact with their surroundings in terms of heat transfer.

Lesson Objective: Understand the difference between heat and temperature

System and Surroundings

universe = system + surroundings

SYSTEM
contents/chemicals in the reaction



SURROUNDINGS
everything else in the universe

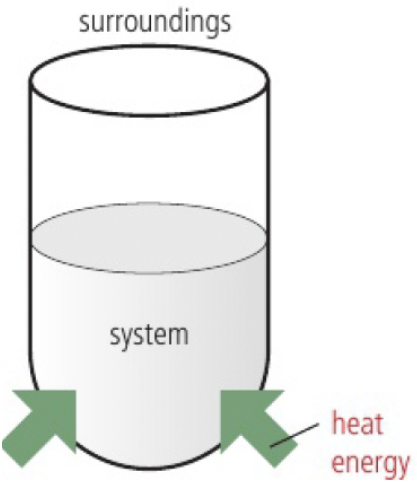
The surroundings are never a part of the system, they're separate concepts.

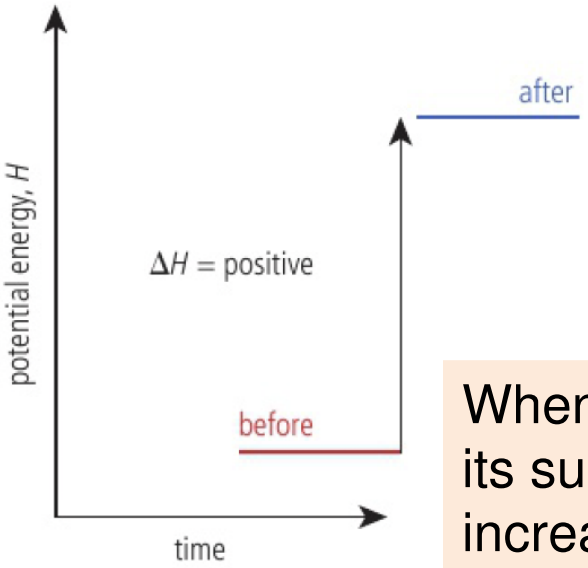
Conservation of energy – the total energy of the system and surroundings cannot change during a process, heat can be transferred between a system and its surroundings energy.

- Energy is exchanged between a system and the surroundings
- Energy lost by the system is gained by the surroundings and vice versa
- Heat flows from hot to cold.

Lesson Objective: Understand the difference between heat and temperature

Chemical potential energy of a system – Enthalpy

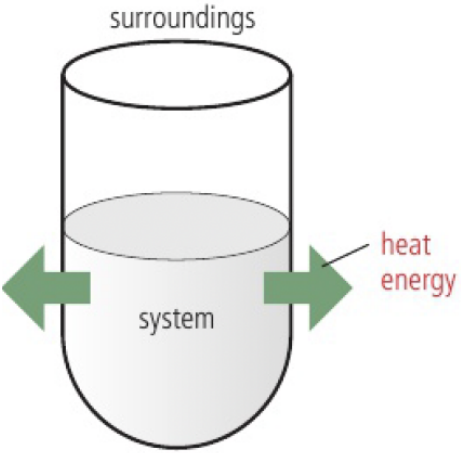


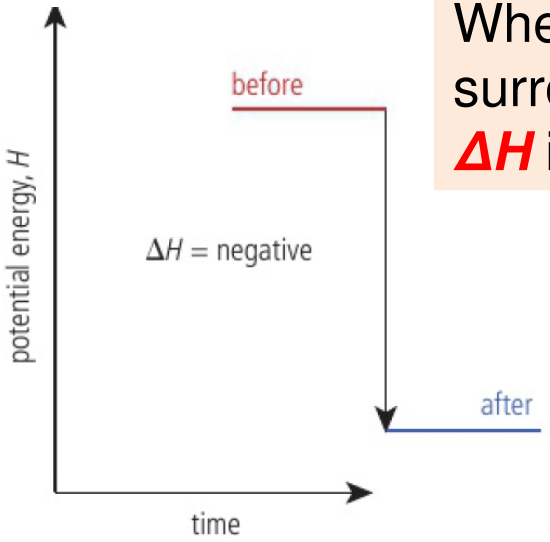


Enthalpy (H) is a measure of the chemical potential energy stored in a system. It changes as chemical bonds and IMFs change during a reaction.

When heat is added to a system from its surroundings, its enthalpy increases, ***ΔH*** is positive.

Heat can be transferred between a system and its surroundings





When heat is lost from a system to its surroundings, its enthalpy decreases, ***ΔH*** is negative.

Lesson Objective: Understand the difference between heat and temperature

Learning Check

Q1. A large iron cube at high temperature, T_H, is brought into contact with a small iron cube at lower temperature, T_C. Discuss the changes that occur, assuming that both objects are insulated from all other objects.

Same material, so same specific heat capacity. Blocks reach the same temperature by equilibrium through transfer by convection.

Q2. The temperature of a volume of water increases from 300 K to 310 K. State the temperature increase in °C. 10°C. Change is the same across units.

Q1. Heat is transferred from the object with a high temperature T_H to the object at temperature T_C.

The two objects will have the same final temperature. The final temperature is closer to T_H than T_C.

Q2. $\Delta T = 310 - 300 = 10$ K

$\Delta T = (310 - 273.15) - (300 - 273.15) = 10$ °C

$T = (310 - 273.15) - (300 - 273.15) = 10$ °C

Lesson Objective: Understand the difference between heat and temperature

Exit Ticket

 **5 mins**

Activity

Imagine a glass of water containing ice cubes sitting in the summer sun. It will undergo a change in enthalpy.

- Is the glass of water an open, closed or isolated system?
  Open.
- Identify the system and the surroundings.
  System is the ice cube, water, and glass
- Explain the movement of energy in the form of heat, between the system and the surroundings.

- What would you observe on the outside of the glass? Explain this observation in terms of a change of state and transfer of energy.

Reactivity 1.1—Measuring enthalpy changes 1.1.2

Guiding question: *What can be deduced from the temperature change that accompanies chemical or physical change?*

Reactivity 1.1.2—Reactions are described as endothermic or exothermic, depending on the direction of energy transfer between the system and the surroundings. Understand the temperature change (decrease or increase) that accompanies endothermic and exothermic reactions, respectively.	
	Tool 1, Inquiry 2—What observations would you expect to make during an endothermic and an exothermic reaction?

Endothermic and Exothermic Reactions

Do Now

Experiment 1

Equipment Needed:

- Hydrochloric acid (HCl), typically 1 M
- Sodium hydroxide (NaOH), typically 1 M
- Beaker (250 mL)
- Thermometer
- Stirring rod
- Graduated cylinder for measuring liquids

Procedure:

1. Measure 50 mL of 1 M hydrochloric acid (HCl) using a graduated cylinder and pour it into a beaker.
2. Measure 50 mL of 1 M sodium hydroxide (NaOH) using a separate graduated cylinder.
3. Place a thermometer in the beaker with the hydrochloric acid and record the initial temperature.
4. Gradually add the sodium hydroxide solution to the beaker containing hydrochloric acid while stirring gently with a stirring rod.
5. Observe the temperature change as the two solutions react.
6. Record the highest temperature reached during the reaction.

Experiment 2

Equipment Needed:

- Ammonium nitrate (NH_4NO_3) crystals
- Beaker
- Stirring rod
- Thermometer
- Distilled water

Procedure:

1. Measure a specific amount of ammonium nitrate crystals.
2. Pour a small amount of distilled water into a beaker.
3. Add the ammonium nitrate to the water while stirring continuously.
4. Measure the temperature of the solution before and after the dissolution process.

23.7°C → 30.7°C

(Experiment 1)

| −0.9°C

(Experiment 2)

R.1.1.2 **Lesson Objective**: Understand the difference between exothermic and endothermic reactions

Do Now

Experiment 1 Analysis

1. What type of reaction occurs when sodium hydroxide reacts with hydrochloric acid?

A. Oxidation
B. Reduction
C. Neutralization ✓
D. Precipitation

2. Which of the following is a product of the reaction between sodium hydroxide and hydrochloric acid?

E. Sodium metal
F. Water
G. Hydrogen gas ✗
H. Sodium carbonate

Acid + Base → Salt + Water
$HCl + NaOH \rightarrow NaCl + H_2O$

3. What happens to the temperature of the solution when sodium hydroxide is mixed with hydrochloric acid?

I. It decreases
J. It remains the same
K. It increases ✓
L. It fluctuates randomly

4. Which of the following best describes the reaction between sodium hydroxide and hydrochloric acid?

M. Endothermic reaction
N. Exothermic reaction ✓
O. Combustion reaction
P. Decomposition reaction

5. What is the main reason for the temperature increase during the reaction between sodium hydroxide and hydrochloric acid?

Q. Release of light energy
R. Absorption of heat from the surroundings
S. Release of heat energy ✓
T. Absorption of sound energy

Experiment 2 Analysis

1. What happens to the temperature of the water when ammonium nitrate is dissolved in it?

A. It increases
B. It remains the same
C. It decreases
D. It fluctuates randomly

2. What type of reaction occurs when ammonium nitrate dissolves in water?

E. Exothermic reaction
F. Endothermic reaction
G. Combustion reaction
H. Decomposition reaction

3. Which of the following best explains why the temperature of the solution decreases when ammonium nitrate dissolves in water?

I. Heat is released from the solution
J. The water absorbs heat from the surroundings
K. Heat is absorbed by the ammonium nitrate from the water
L. No heat is transferred

4. When ammonium nitrate dissolves in water, what is the sign of the enthalpy change (ΔH) for the process?

M. Positive
N. Negative
O. Zero
P. Undefined

5. Which of the following describes the dissolution of ammonium nitrate in water?

Q. It releases energy to the surroundings
R. It absorbs energy from the surroundings
S. It does not involve any energy change
T. It produces light

 Lesson Objective: Understand the difference between exothermic and endothermic reactions

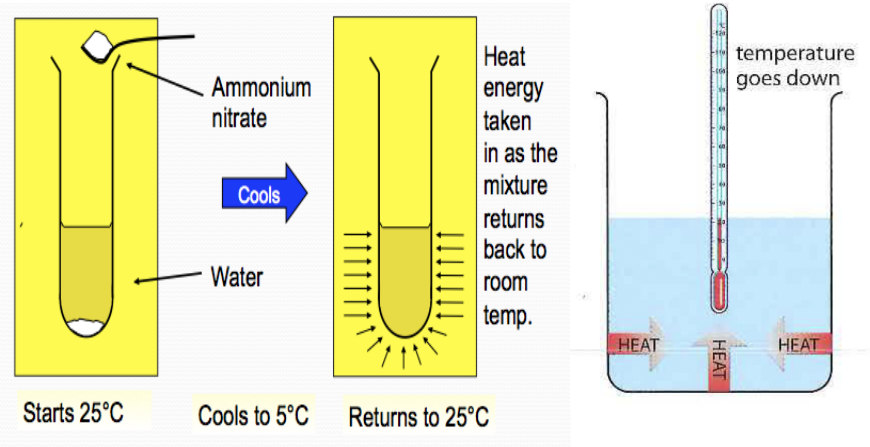
Exothermic and Endothermic Reactions

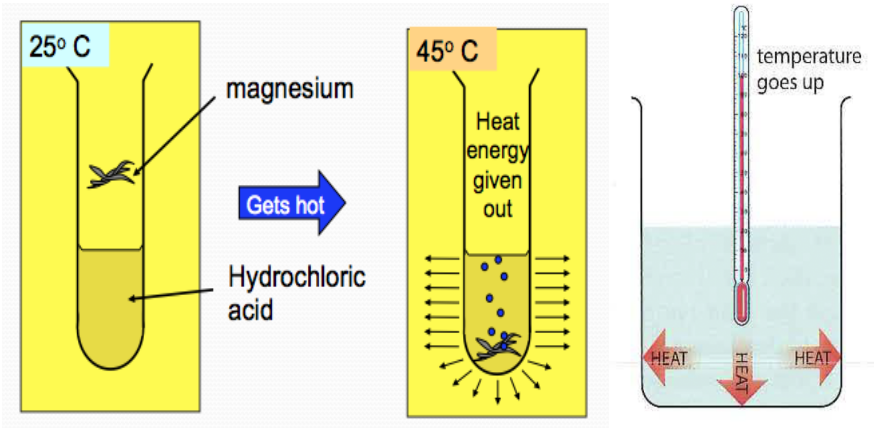
Endothermic Reactions

- A system (chemical reaction) takes in heat energy from the surroundings – the surroundings get colder.
- Energy is absorbed by the system
- Reactants convert heat energy into chemical energy as they change into products.
- The temperature drops/decreases.

Exothermic Reactions

- Heat energy is transferred from the system (chemical reaction) to the surroundings – the surroundings get hotter
- Energy is released by the system
- Reactants convert chemical energy to heat energy.
- Temperature rises/increases





 Lesson Objective: Understand the difference between exothermic and endothermic reactions

Exothermic and Endothermic Reactions

endothermic

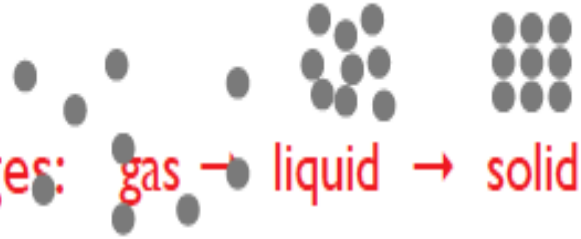
state changes: solid → liquid → gas

melting and evaporation

chemical changes: various!

exothermic

state changes: gas → liquid → solid



condensation and solidification

chemical changes: combustion reactions

Always exothermic!

neutralization reactions

(acid + base)

Reactivity 1.1—Measuring enthalpy changes 1.1.3

Guiding question: *What can be deduced from the temperature change that accompanies chemical or physical change?*

Reactivity 1.1.3—The relative stability of reactants and products determines whether reactions are endothermic or exothermic. Sketch and interpret energy profiles for endothermic and exothermic reactions.	
Axes for energy profiles should be labelled as reaction coordinate (x), potential energy (y).	Structure 2.2—Most combustion reactions are exothermic; how does the bonding in N_2 explain the fact that its combustion is endothermic?

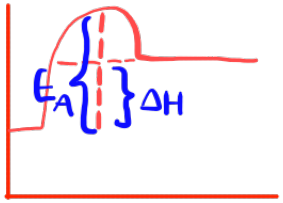
Energetic stability and the direction of change

Lesson Objective: Understand what is meant by the term stability; Sketch and interpret potential energy profiles

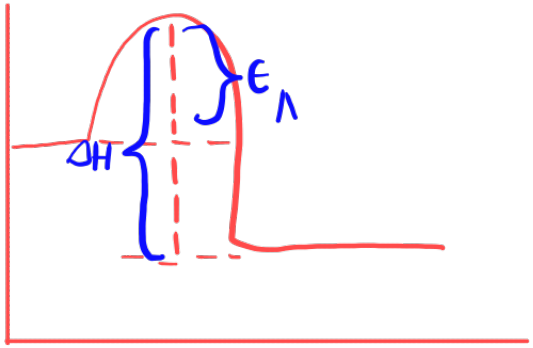
Do Now

5 mins

1. Sketch an energy profile for an endothermic reaction.
2. Label the activation energy (the energy barrier that must be overcome for the reaction to proceed) and the overall energy absorbed by the system.



3. Sketch an energy profile for an exothermic reaction.
4. Label the activation energy and the overall energy released during the reaction.

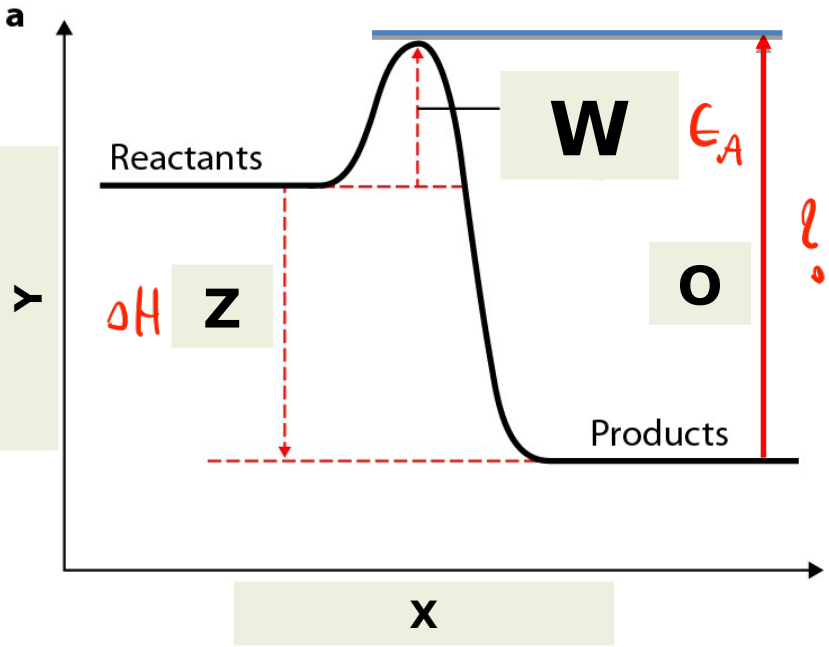


 Lesson Objective: Understand what is meant by the term stability; Sketch and interpret potential energy profiles

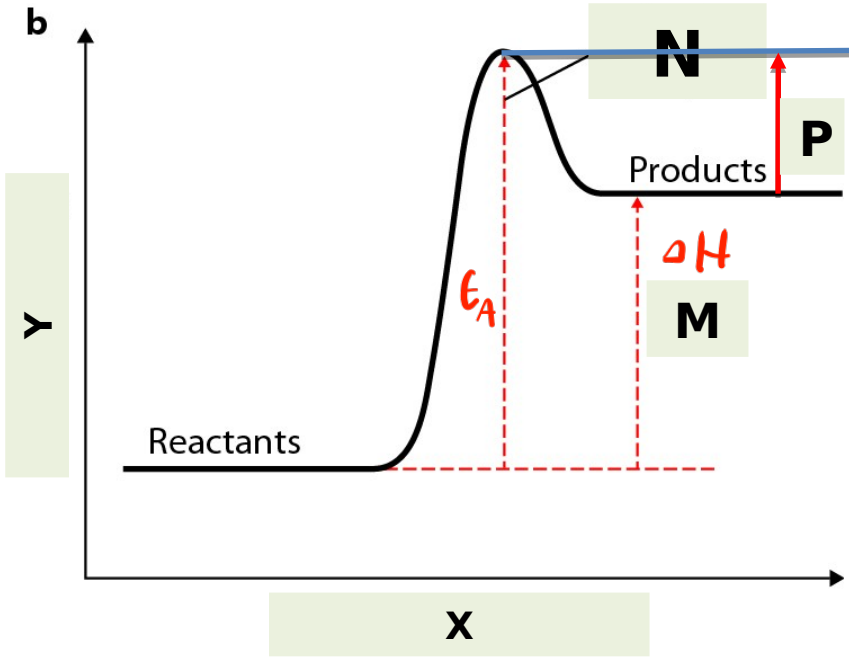
Stability and Potential Energy Profiles

Label the following potential energy profiles.

a

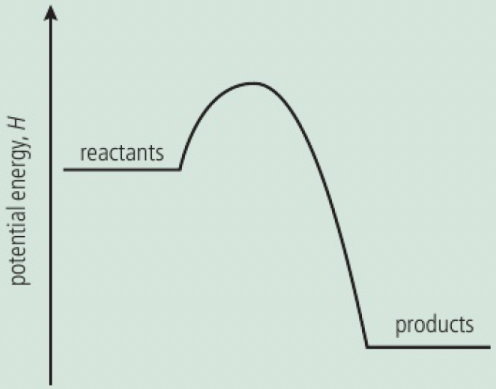


b



Learning Check

Q7. Which statement is consistent with the potential energy profile shown?



A Heat is produced during the reaction and the products are more stable than the reactants.

B Heat is taken in during the reaction and the products are more stable than the reactants.

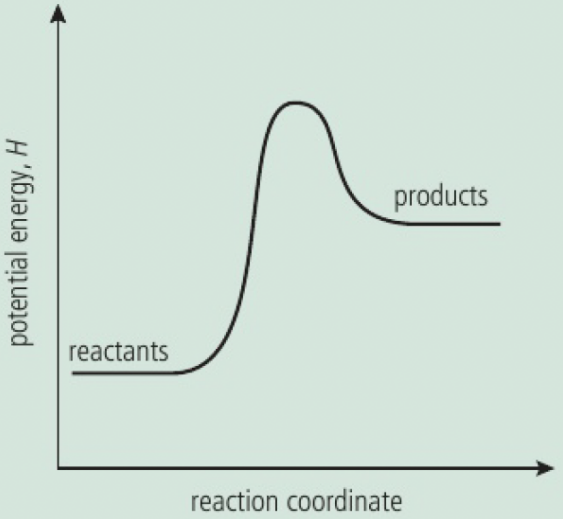
C Heat is produced during the reaction and the reactants are more stable than the products.

D Heat is taken in during the reaction and the reactants are more stable than the products.

Q8. Identify the endothermic reaction.

	Enthalpy	Direction of heat transfer
A	$H_{reactants} < H_{products}$	system → surroundings
B	$H_{reactants} < H_{products}$	surroundings → system
C	$H_{reactants} > H_{products}$	system → surroundings
D	$H_{reactants} > H_{products}$	surroundings → system

Q9. The potential energy profile of a reaction is shown.



What can be deduced about the nature of the reaction and the relative stability of the reactants and products?

	Nature of reaction	Most stable
A	endothermic	reactants
B	endothermic	products
C	exothermic	reactants
D	exothermic	products

 Lesson Objective: Understand what is meant by the term stability; Sketch and interpret potential energy profiles

Exit Ticket

 **5 mins**

Barium hydroxide, $Ba(OH)_2$, reacts with ammonium chloride, NH_4Cl:

$$Ba(OH)_2(s) + 2NH_4Cl(s) \rightarrow BaCl_2(aq) + 2NH_3(g) + 2H_2O(l) \quad \Delta H = +164 \text{ kJ mol}^{-1}$$

Which of the following is correct for this reaction?

	Temperature	Enthalpy	Stability
A	increases	products have lower enthalpy than the reactants	products are less stable than the reactants
B	decreases	products have lower enthalpy than the reactants	products are more stable than the reactants
C	decreases	products have higher enthalpy than the reactants	products are less stable than the reactants
D	increases	products have higher enthalpy than the reactants	products are more stable than the reactants

Temperature is absorbed from the environment therefore temperature of the surroundings decreases.