



Master Kirkcaldy High School



Higher Chemistry Unit 3 - part 2 Controlling the Rate and Energy

Name: _____

Class: _____

Teacher: _____

Assessment Page

Homework

Homework title	Date	Mark/Total Mark
		/

Notes/comments

Check tests

Test title	Date	Mark/Total Mark
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Notes/comments

Controlling the Rate

Overarching question(s) for this topic

- What are the requirements for a successful collision to occur and how does the energy within chemicals affect the energy changes during a reaction?
-

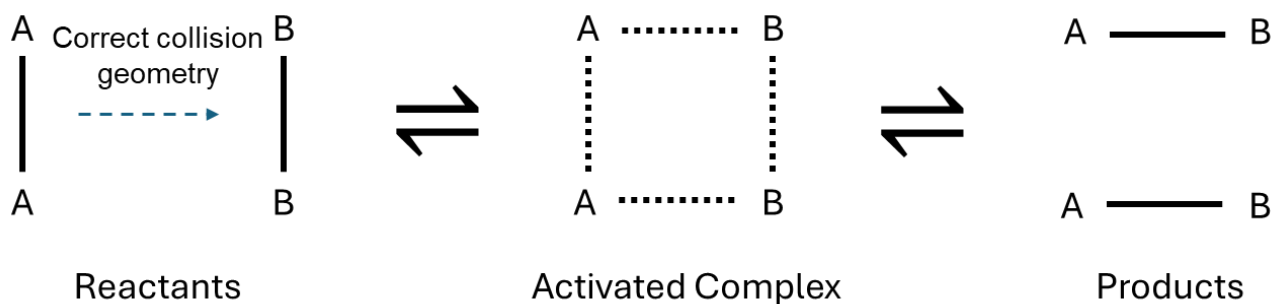
Requirements for a Successful Collision

For a reaction to occur, there must be a successful collision. The two requirements for a successful collision are:

1. The particles must collide with **sufficient** energy to reach the **activation energy (E_a)**.
2. The particles must have the correct **collision geometry** (they must collide at the correct angle).

The **activation energy** is the minimum energy required by colliding particles to form an **activated complex**.

Diagram of a successful collision:



Factors that influence the rate of reaction

Factor	Explanation	Effect on Reaction Rate
Concentration	- Increasing the concentration of reactants increases the number of particles in a given volume, leading to more frequent collisions.	- Higher concentration increases the reaction rate because there are more collisions, increasing the chance of effective collisions.
Pressure (for gases)	- Increasing the pressure of a gas reduces the volume available, bringing gas particles closer together, effectively increasing concentration.	- Higher pressure increases the reaction rate by increasing the frequency of collisions between gas molecules.
Surface Area (particle size)	- Reducing the particle size increases the surface area exposed to reactants, allowing more collisions at the surface.	- Smaller particles or increased surface area result in more frequent collisions, thereby increasing the reaction rate.
Temperature	- Increasing temperature provides more kinetic energy to the particles, making them move faster and collide with greater energy.	- Higher temperature increases the reaction rate because particles collide more frequently and with sufficient energy to overcome the activation energy.

Reaction Pathways

A potential energy diagram can be used to show the **energy pathway** for a reaction.

These diagrams show the **chemical energy (enthalpy)** changes as **reactants form products** during the **forward** reaction and **products reform the reactants** during the **backwards** reaction.

The diagrams also show the **activation energy (E_a)** for both the **forward** and **backwards** reaction.

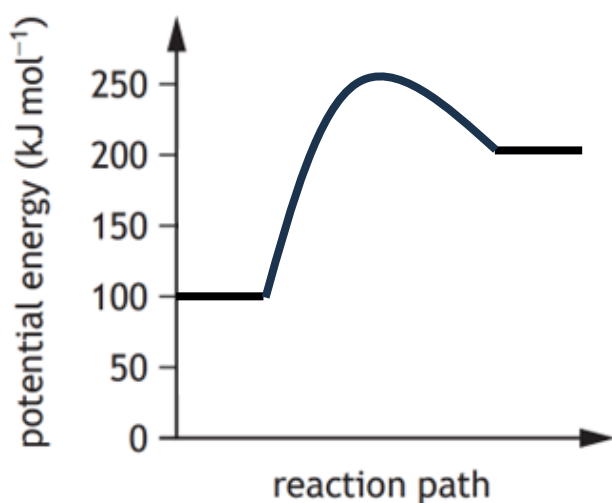
The **enthalpy change (ΔH)** is the energy difference between the **products** and the **reactants**, measured in **kJ mol⁻¹**.

If the products have greater chemical energy than the reactants it is an **endothermic reaction** and will have a positive value (e.g. +100 kJ mol⁻¹).

If the products have less chemical energy than the reactants it is an **exothermic reaction** and will have a negative value (e.g. -100 kJ mol⁻¹).

The enthalpy change and activated energy of the forward and backward reaction can be calculated using the diagrams:

Endothermic Reaction Pathway



Forward Reaction:

$$\Delta H =$$

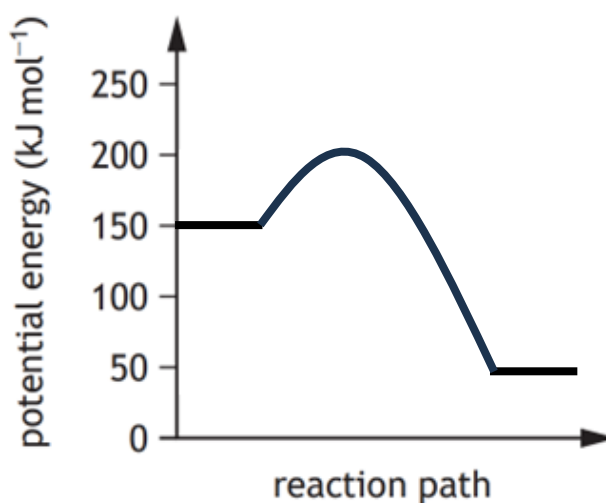
$$E_a =$$

Backward Reaction:

$$\Delta H =$$

$$E_a =$$

Exothermic Reaction Pathway



Forward Reaction:

$$\Delta H =$$

$$E_a =$$

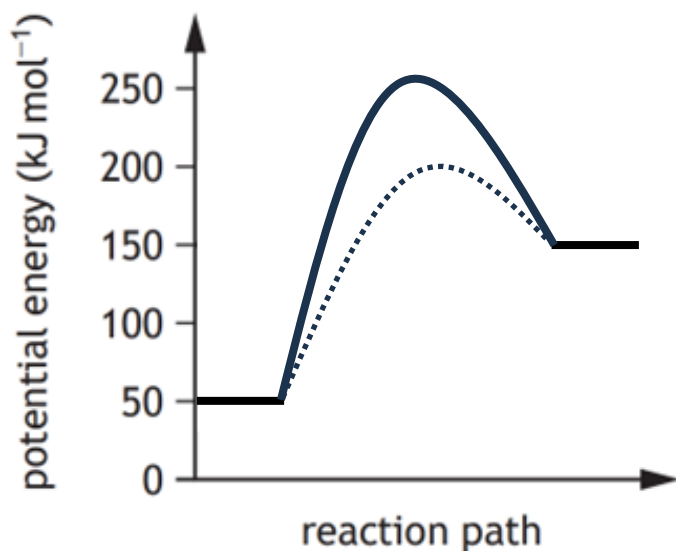
Backward Reaction:

$$\Delta H =$$

$$E_a =$$

Effect of a catalyst

A catalyst provides an alternative reaction pathway with a **lower activation energy (E_a)**.



Forward Reaction:

$$\Delta H =$$

$$E_{a_{\text{uncatalysed}}} =$$

$$E_{a_{\text{catalysed}}} =$$

Backward Reaction:

$$\Delta H =$$

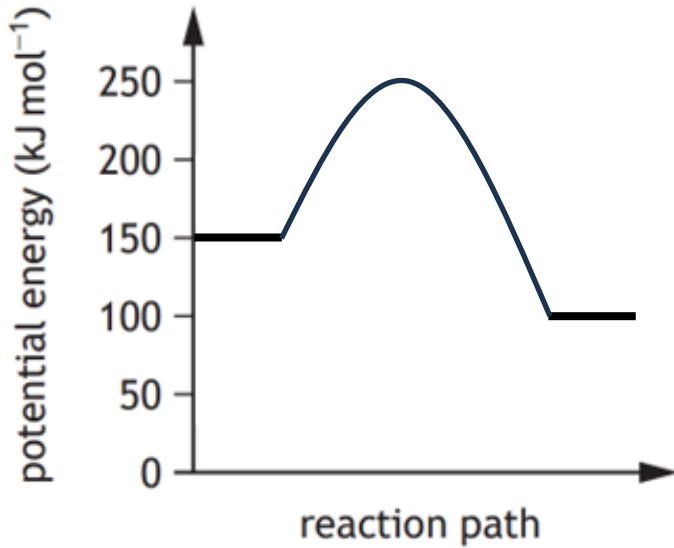
$$E_{a_{\text{uncatalysed}}} =$$

$$E_{a_{\text{catalysed}}} =$$

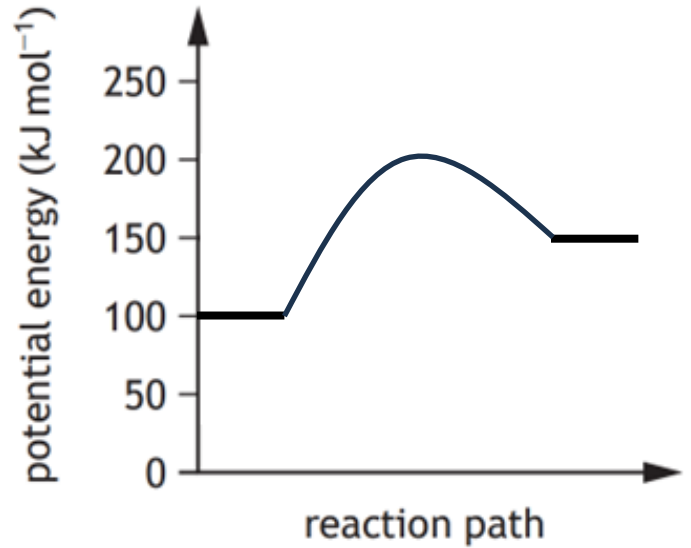
Questions:

Calculate the ΔH and E_a of the forward and backward reaction with the following diagrams. Describe the diagram as either an endothermic or exothermic reaction.

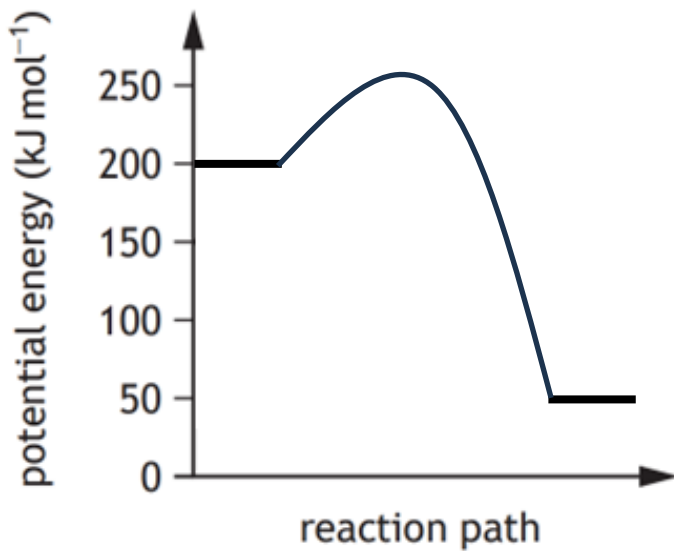
a.



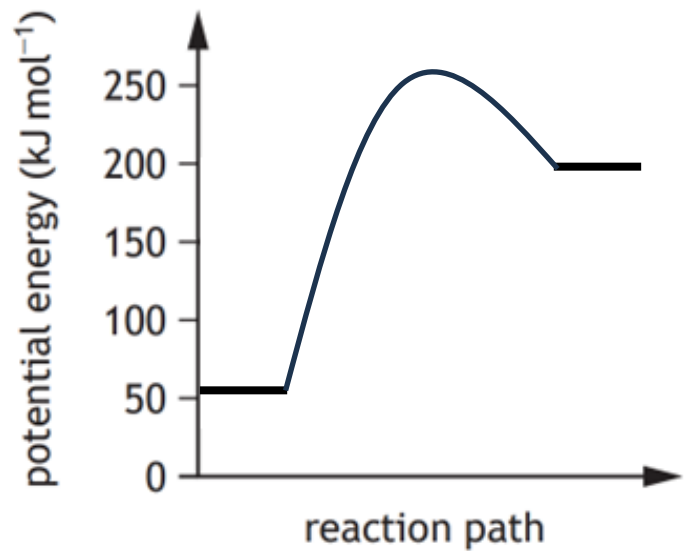
b.



c.



d.



Kinetic Energy Diagrams

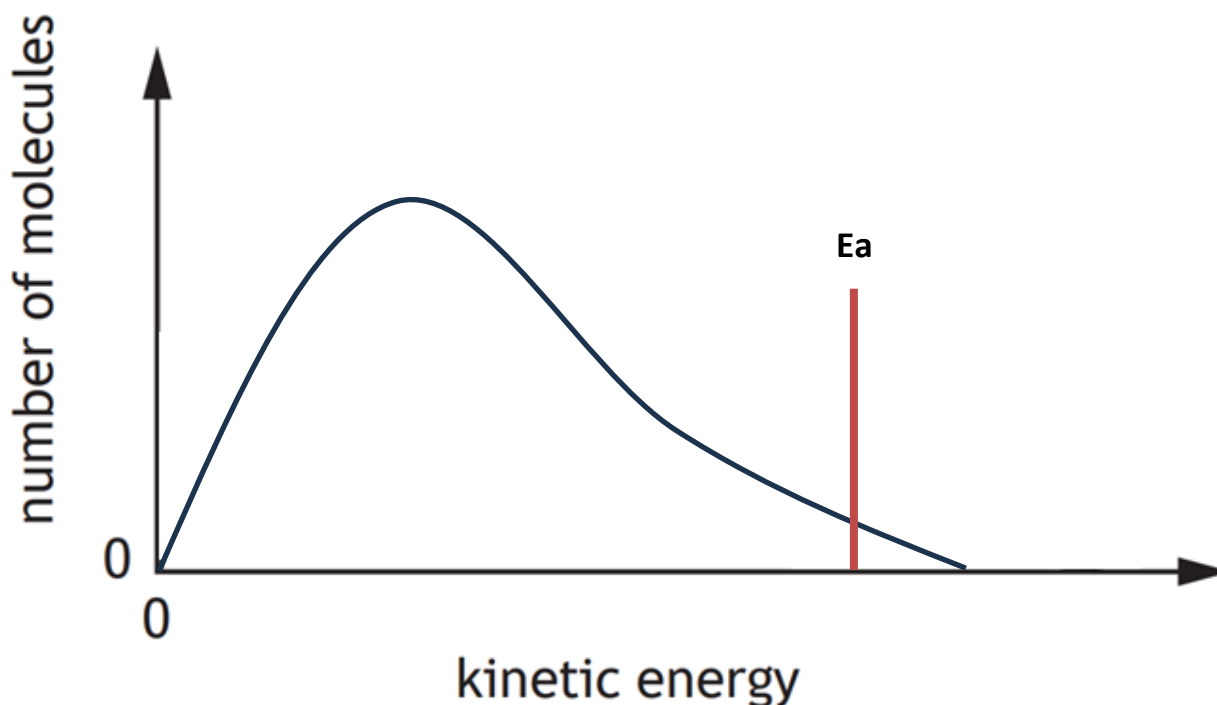
In order to visualise and measure the number of particles that have sufficient energy to reach the activation energy (requirement 1 of a successful collision) we can use kinetic energy diagrams.

This does not guarantee a successful collision, they must also have the correct collision geometry.

Temperature is a measure of the **average kinetic energy** of the particles in a substance.

The activation energy is the **minimum kinetic energy** required by colliding particles before a reaction **may** occur.

Energy distribution diagrams can be used to explain the effect of changing temperature on the kinetic energy of particles and reaction rate:

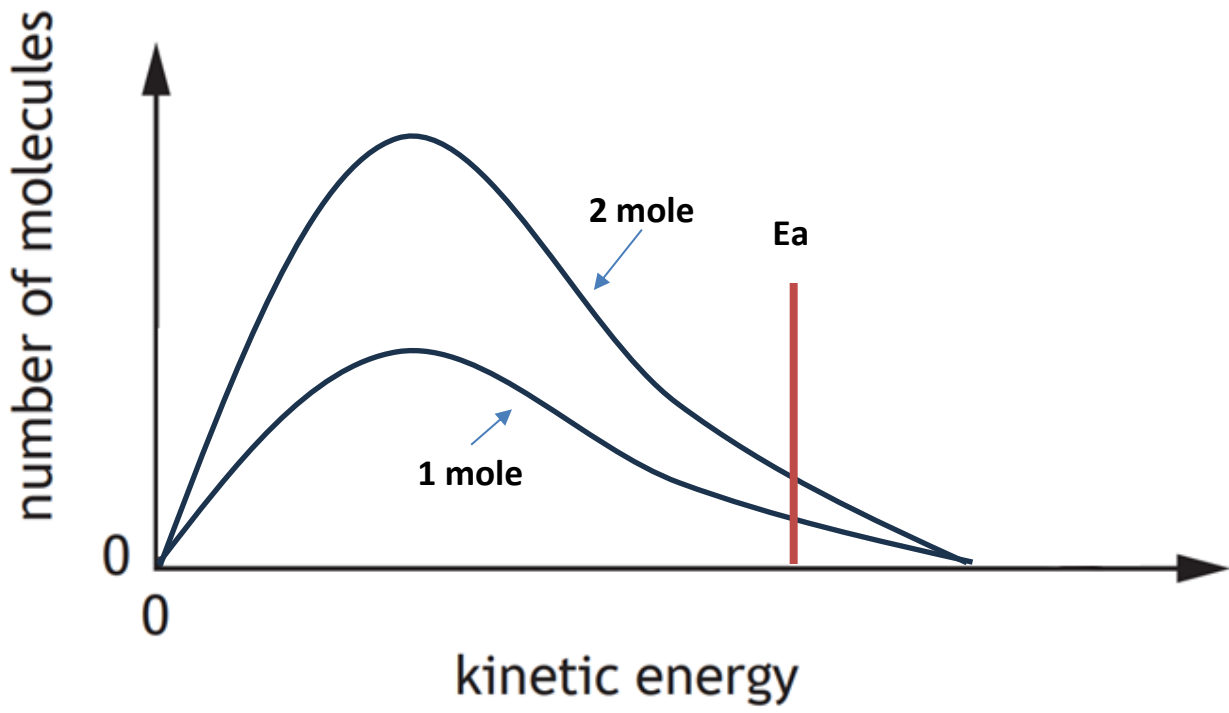


Increasing the temperature moves the peak of the curve to the **right** and **down**, **increasing** the number of particles with sufficient energy to reach the activation energy and form an activated complex.

Decreasing the temperature moves the peak of the curve to the **left** and **up**, **decreasing** the number of particles with sufficient energy to reach the activation energy and form an activated complex.

The addition of a catalyst moves the E_a to the **left**.

Effect of changing concentration



Measuring the Rate

If a gas is produced a gas syringe or balance can be used to measure the rate of gas production or mass lost. The average rate of reaction can be measured by using the following reaction:

$$\text{Average rate} = \frac{\Delta \text{Quantity}}{\Delta \text{Time}}$$

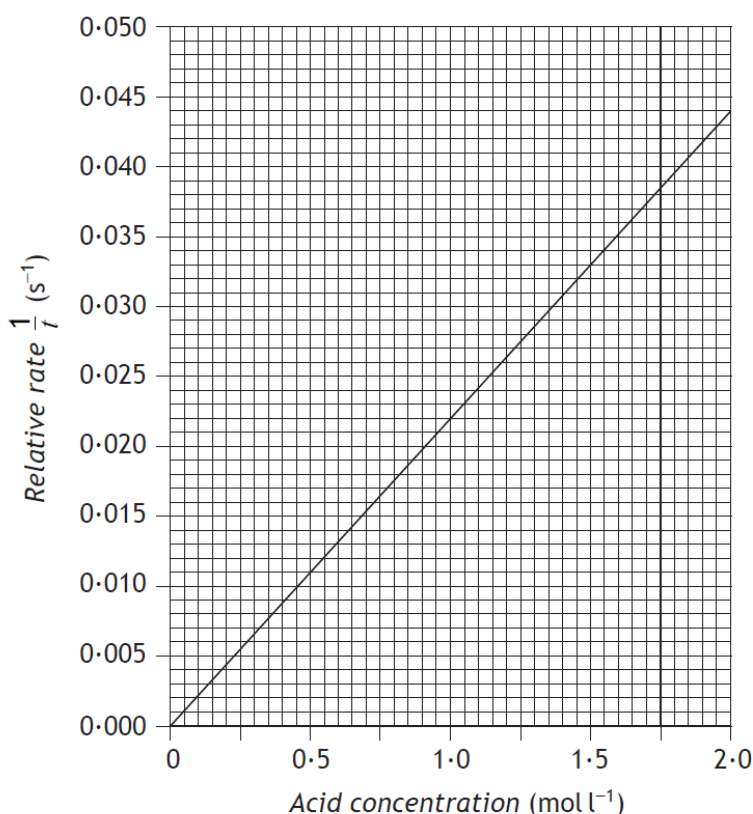
Not all reactions involve the production of gas and different methods must be used to measure the rate.

The rate of reaction of reactions involving a change in colour can be determined using a stopwatch. When all the reactants are added together the timer is started and stopped when the colour changes. This will then be repeated at with different concentrations of reactants.

The reaction times are then converted to **relative rates** using the formula:

$$\text{Relative rate}(S^{-1}) = \frac{1}{\text{reaction time}(s)}$$

Concentration is plotted against relative rate:



From the graph the specific concentration can be used to find the reaction time by using the opposite equation:

$$\text{Reaction Time}(s) = \frac{1}{\text{reaction time}(S^{-1})}$$

Flash Cards

Past Papers

S & B 1st 20	2015	2016	2017	2018	2019	2021	2022	2023
MC	19	4		1,2,3	20,22,24	16,17,18	18,21	4,5,6
S2	2	1a,c	2aii/aiv		9a	4eiiB,7d	2bii,2biv,8ai	6ai,6b

TEAMS: Check Test – Unit 1: Key Area 3b

Chemical Energy

Overarching question(s) for this topic

- How can we calculate the energy release when a mole of substance is burned?
- How can we calculate the energy gained or lost in a reaction just given a chemical equation?

Enthalpy

Enthalpy is a measure of the chemical energy in a substance.

A reaction or process that releases heat energy is described as exothermic.

In industry, exothermic reactions may require heat to be removed to prevent the temperature rising.

A reaction or process that takes in heat energy is described as endothermic.

In industry, endothermic reactions may incur costs in supplying heat energy in order to maintain the reaction rate.

Enthalpy of Combustion

The **enthalpy of combustion** of a substance is the enthalpy change when **one mole** of the substance burns **completely** in **oxygen**.

During **complete combustion** of a hydrocarbon, **carbon dioxide** and **water** are produced.

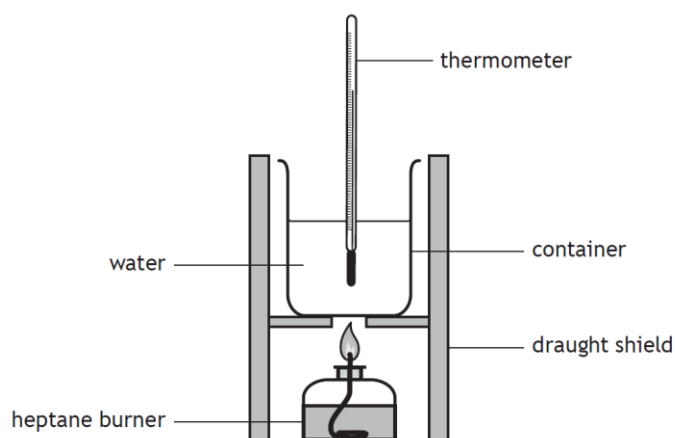
The quantity of heat energy released can be determined experimentally and calculated using:

$$Eh = cm\Delta T$$

The spirit burner must be weighed **before** and **after** combustion to find the **mass** of fuel burned.

The energy released from this mass of fuel can then be scaled up to the GFM to find the enthalpy of combustion.

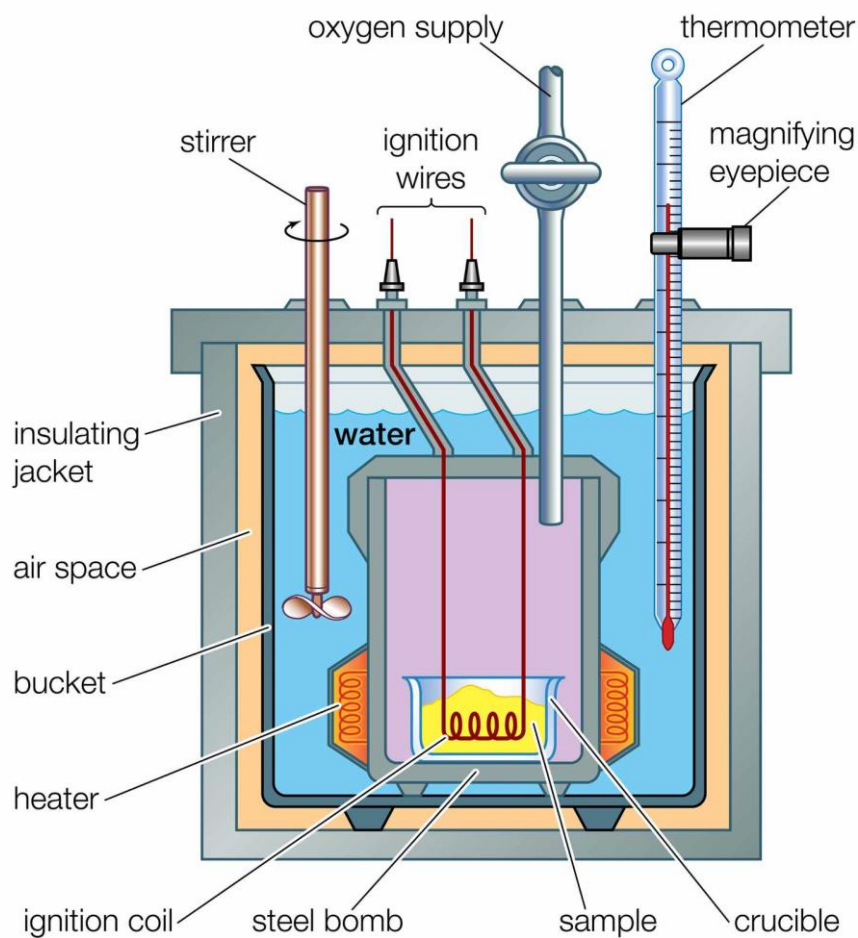
Calculation Example



Mass of heptane burned (g)	1.1
Mass of 1 mole of heptane (g)	100.0
Volume of water used (cm ³)	400
Initial temperature of water (°C)	26
Final temperature of water (°C)	49

The literature enthalpy of combustion is -4817 kJ/mol, explain why there is a difference:

The values for enthalpy of combustion found in data booklet and literature are measured using a bomb calorimeter:



List the ways in which the bomb calorimeter limits the energy loss from combustion:

Questions

1. Given that you burned 0.95 g of ethanol ($\text{C}_2\text{H}_5\text{OH}$), to heat up 100 cm^3 of water, with an initial water temperature of 18.5°C and a final temperature of 45.0°C , calculate the enthalpy of combustion of ethanol.
2. You burned 1.2 g of methanol (CH_3OH), and the temperature of 150 cm^3 of water increased from 20.0°C to 45.0°C . Calculate the enthalpy of combustion of methanol.
3. 1.5 g of propanol ($\text{C}_3\text{H}_7\text{OH}$) was burned, causing the temperature of 200 cm^3 of water to increase from 22.0°C to 55.0°C . Calculate the enthalpy of combustion of propanol.
4. You burned 0.75 g of butanol ($\text{C}_4\text{H}_9\text{OH}$) and measured a temperature increase in 120 cm^3 of water from 19.0°C to 40.5°C . Calculate the enthalpy of combustion of butanol.
5. Burning 2.0 g of pentanol ($\text{C}_5\text{H}_{11}\text{OH}$) resulted in a temperature increase from 24.0°C to 60.0°C in 250 cm^3 of water. Calculate the enthalpy of combustion of pentanol.

Using energy and enthalpy of combustion to calculate the moles/mass

If the enthalpy of combustion and the energy released (or can be calculated) is given the moles can be calculated given the formula:

$$\text{moles} = \frac{\text{energy released}}{\text{enthalpy of combustion}}$$

This always works with any molar enthalpy value.

Example:

Methane, CH_4 , can be used as a fuel.

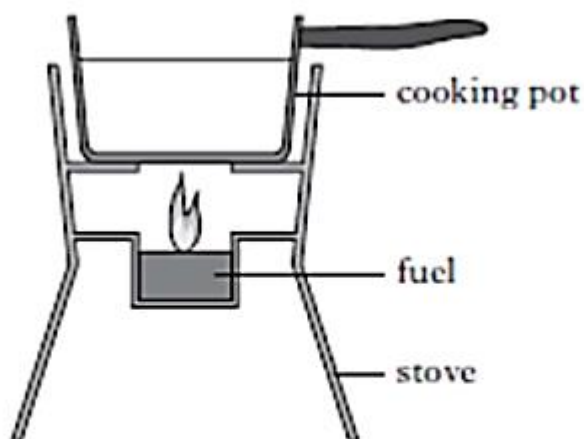
In an experiment, methane was burned to raise the temperature of 100 cm^3 of water by $27 \text{ }^\circ\text{C}$.

Using the enthalpy of combustion of methane (891 kJ mol^{-1}), calculate the mass of methane, in g, burned in this experiment.

Questions

1.

Ethanol, $\text{C}_2\text{H}_5\text{OH}$, can be used as a fuel in some camping stoves.



(a) The enthalpy of combustion of ethanol is $-1367 \text{ kJ mol}^{-1}$.

Using this value, calculate the number of moles of ethanol required to raise the temperature of 500 g of water from $18 \text{ }^\circ\text{C}$ to $100 \text{ }^\circ\text{C}$.

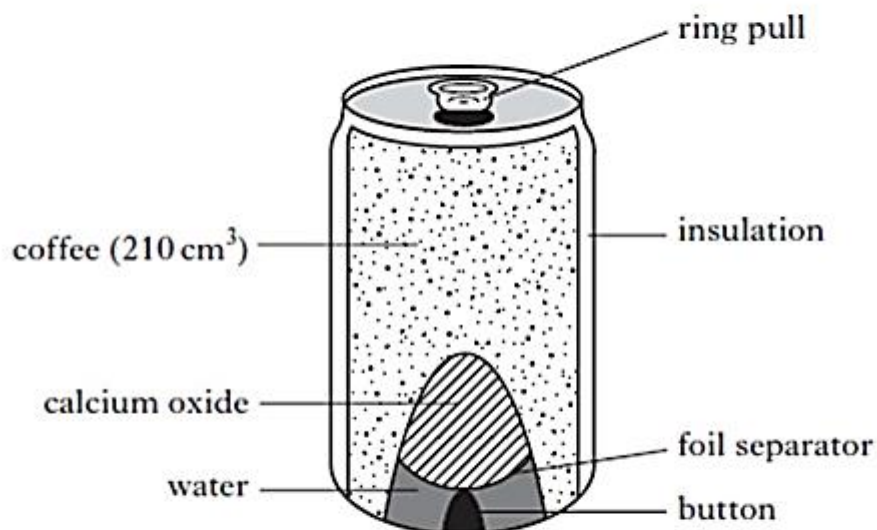
Show your working clearly.

2.

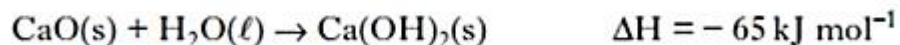
Self-heating cans may be used to warm drinks such as coffee.

When the button on the can is pushed, a seal is broken allowing water and calcium oxide to mix and react.

The reaction produces solid calcium hydroxide and releases heat.



The equation for this reaction is:



- (a) Calculate the mass, in grams, of calcium oxide required to raise the temperature of 210 cm³ of coffee from 20 °C to 70 °C.

Bond Enthalpy

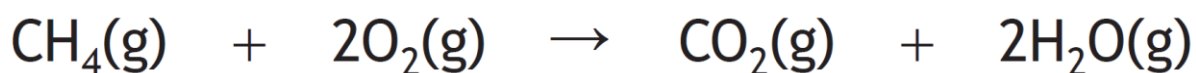
The **molar bond enthalpy** is the energy required to break **one mole** of **bonds** in a **diatomic molecule** (page 11 data booklet).

A **mean molar bond enthalpy** is the **average** energy required to break **one mole** of **bonds**, for a bond that occurs in a **number of compounds**.

Bond enthalpies can be used to estimate the enthalpy change of a reaction by using the following equation:

$$\Delta H = H_{\text{bond breaking}} + H_{\text{bond making}}$$

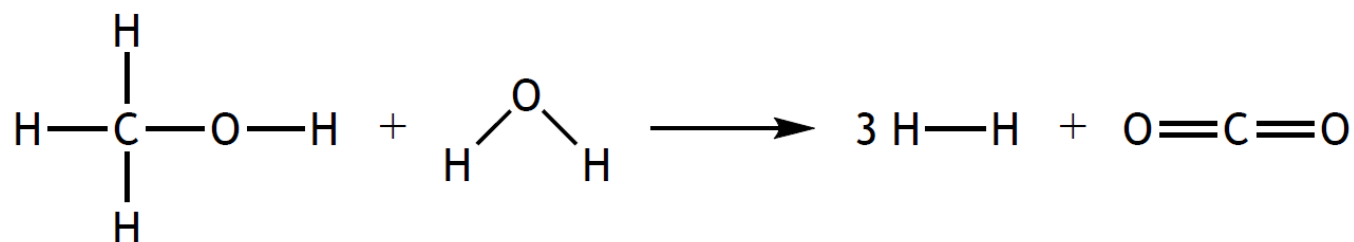
Your teacher will demonstrate an example:



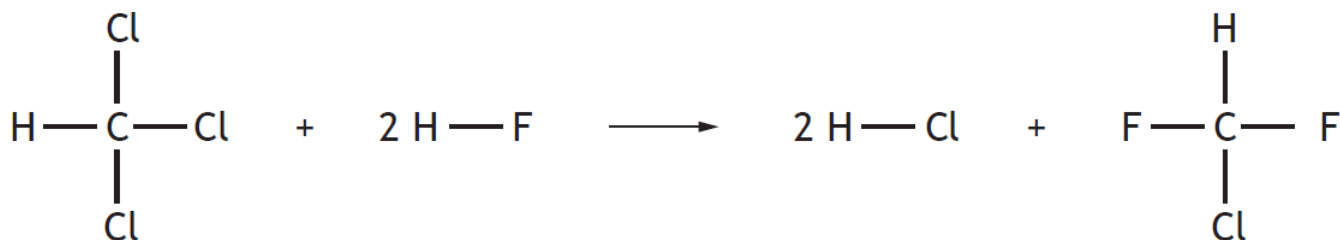
Questions

Calculate the enthalpy change of the following equations using the bond enthalpies:

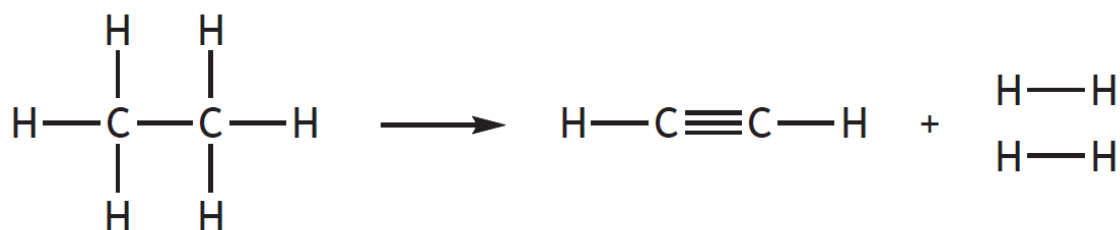
1.



2.



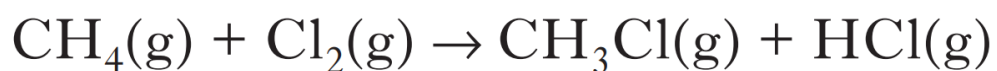
3.



4.

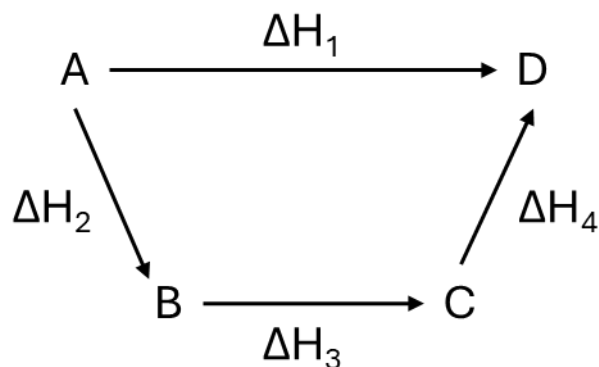


5.



Hess' Law

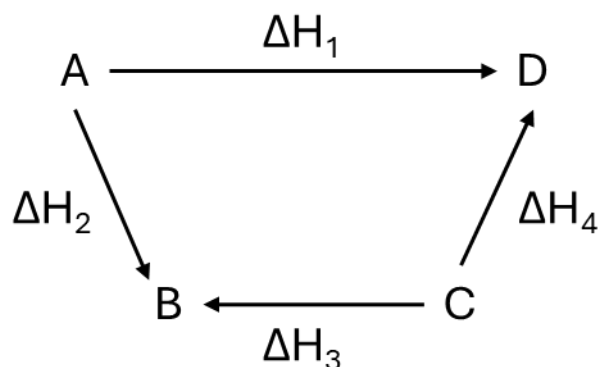
Hess's law states that the enthalpy change for a chemical reaction is **independent** of the route taken.



$$\Delta H_1 = \Delta H_2 + \Delta H_3 + \Delta H_4$$

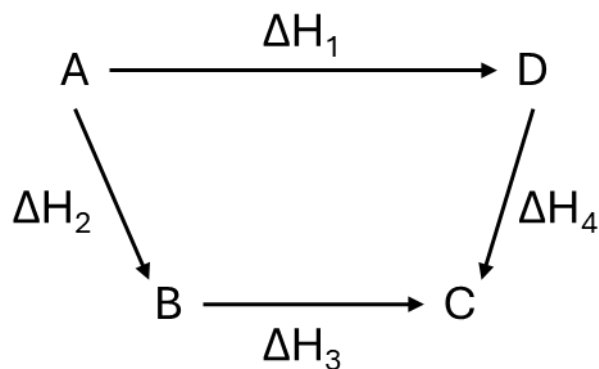
If an arrow is flipped the wrong way, the sign of the value can be changed to change the direction of the arrow:

Example:



$$\Delta H_1 = \Delta H_2 - \Delta H_3 + \Delta H_4$$

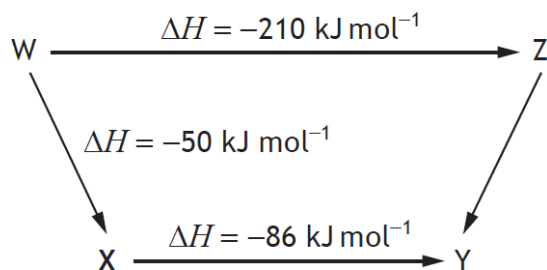
Or



$$\Delta H_1 = \Delta H_2 + \Delta H_3 - \Delta H_4$$

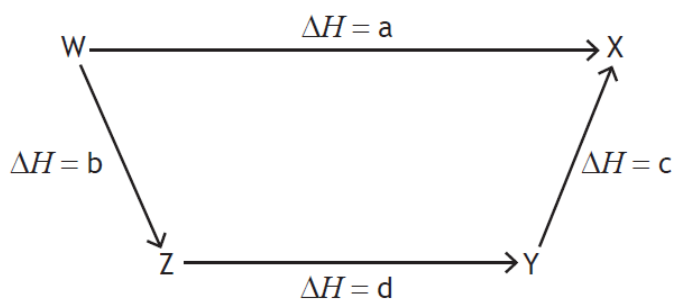
Questions

1. Consider the reaction pathway below:



Using Hess' Law, calculate the the ΔH value, in kJ/mol, for the reaction Z to Y:

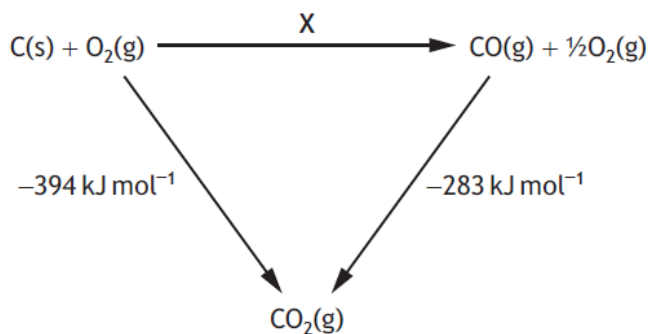
2. Consider the reaction pathway below:



According to Hess' Law

- A $b = a - c - d$
- B $b = a + c + d$
- C $b = d - c + a$
- D $b = d + c - a$.

3. Consider the reaction pathways shown below:

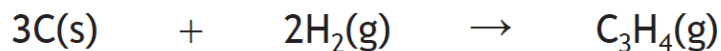


Using Hess' Law, calculate the the ΔH value, in kJ/mol, for reaction X.

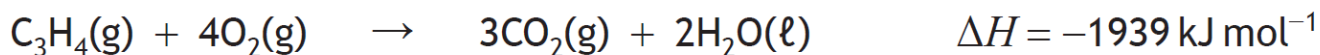
Hess' Law with Equations

Hess's law can also be used given a set of equations. There will always be a target equation at the top and the other equations may be inverted and/or multiplied to combine into the target equation.

Your teacher will demonstrate the method involved to do this below:

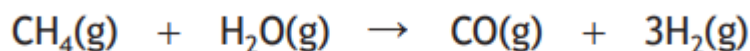


Calculate the enthalpy change, in kJ mol^{-1} , for this reaction using the following information.



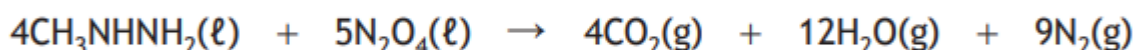
Questions

1. Carbon monoxide can be produced by the reaction of methane and steam.

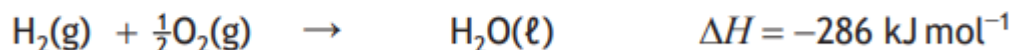
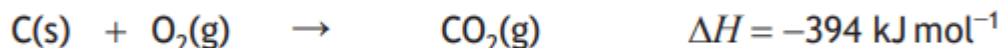
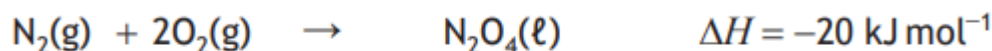
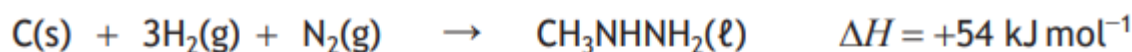


Calculate the enthalpy change, in kJ mol^{-1} , for this reaction.

2. In the United States Space Shuttle, dinitrogen tetroxide was reacted with methylhydrazine.



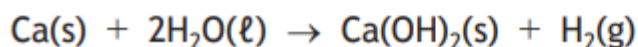
Calculate the enthalpy of this reaction, in kJ, by using the data shown below.



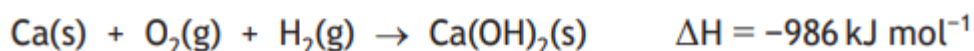
3.

Calcium hydroxide solution can be formed by adding calcium metal to excess water.

Solid calcium hydroxide would form if the exact molar ratio of calcium to water is used. The equation for the reaction is



Calculate the enthalpy change, in kJ mol^{-1} , for the reaction above by using the data shown below.

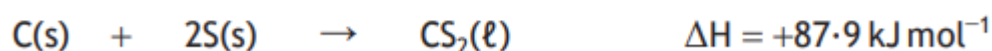
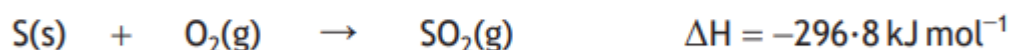
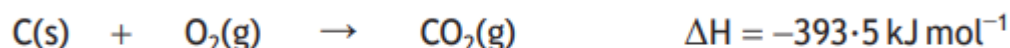


4.

Another reaction that produces sulfur dioxide gas involves combustion of carbon disulfide in the reaction shown.



Calculate the enthalpy change, in kJ mol^{-1} , for this reaction using the following information.



Past Papers

S & B 1 st 20	2015	2016	2017	2018	2019	2021	2022	2023
MC	16,17	14,16	12,18	16,17	21		22	7,12,17
S2	7b-c	8c, 9b	2ai, 4b, 5b	8	5, 9c	2c, 4a,4dii, 5a-bi, 7b	2biii, 7a- b, 7ei	2bi, 7cii

TEAMS: Check Test – Unit 1: Key Area 3c