Chemistry

In society

Mark Dewar

16 O bjectives

1. ENTHALPY
2. HESS'S LAW
3. BOND ENTHALPY

EQUILIBRIUM

EQUILIBRIUM STATE

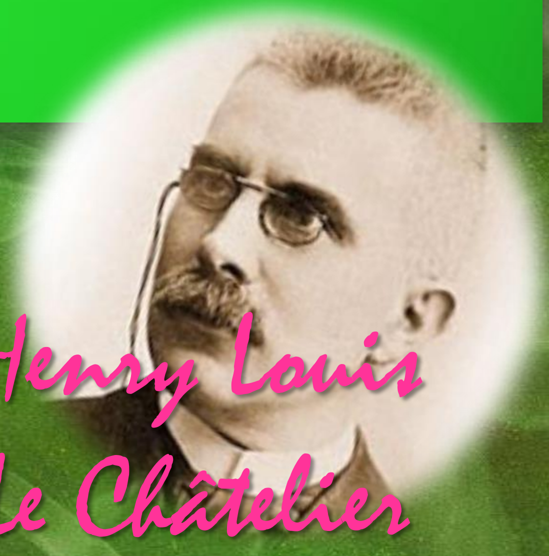
In a **dynamic equilibrium**, the **rate** of the forward reaction is **equal** to the rate of the back reaction.

The concentration of the reactants and products remains **constant** but not necessarily equal.

EQUILIBRIUM

LE CHATELIER'S PRINCIPLE

IF **A STRESS** IS PLACED ON A SYSTEM AT **EQUILIBRIUM**, THE SYSTEM WILL PROCEED IN A DIRECTION THAT **MINIMIZES THE STRESS**.



Henry Louis Le Châtelier

EQUILIBRIUM

LE CHATELIER'S PRINCIPLE

CONCENTRATION

TEMPERATURE

PRESSURE

EQUILIBRIUM

LE CHATELIER'S PRINCIPLE

$$2NO_2(g) \rightleftharpoons N_2O_4\ (g) \qquad \Delta H = -57.2\text{kJ}$$

What conditions would increase forward reaction?

EQUILIBRIUM

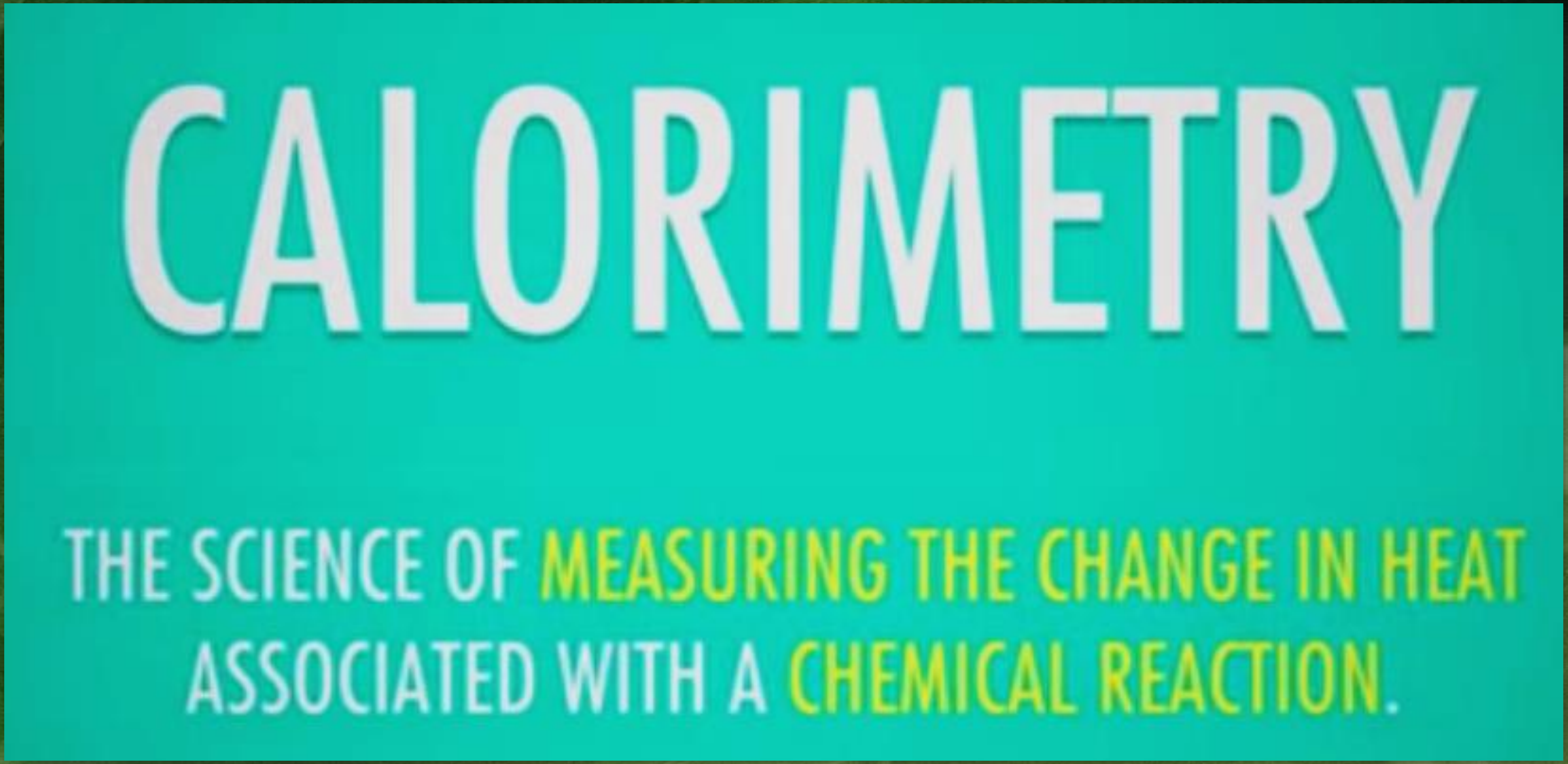
LE CHATELIER'S PRINCIPLE

$2NO_2(g) \rightleftharpoons N_2O_4\ (g) \qquad \Delta H = -57.2 kJ$

Increase PRESSURE

Decrease TEMPERATURE

CALORIMETRY



CALORIMETRY

SPECIFIC HEAT CAPACITY

THE **AMOUNT OF HEAT REQUIRED** TO RAISE THE TEMPERATURE OF **ONE MASS UNIT** OF A SUBSTANCE BY **1.00°C**.

CALORIMETRY

SPECIFIC HEAT CAPACITY

THE **AMOUNT OF HEAT REQUIRED** TO RAISE THE TEMPERATURE OF **ONE MASS UNIT** OF A SUBSTANCE BY **1.00°C.**

The specific heat capacity of a substance is a measure of how much heat energy it can hold.

CALORIMETRY

SPECIFIC HEAT CAPACITY

Substance	Specific heat capacity J/kg/ºC
water	4181
lead	128
oxygen	918

CALORIMETRY

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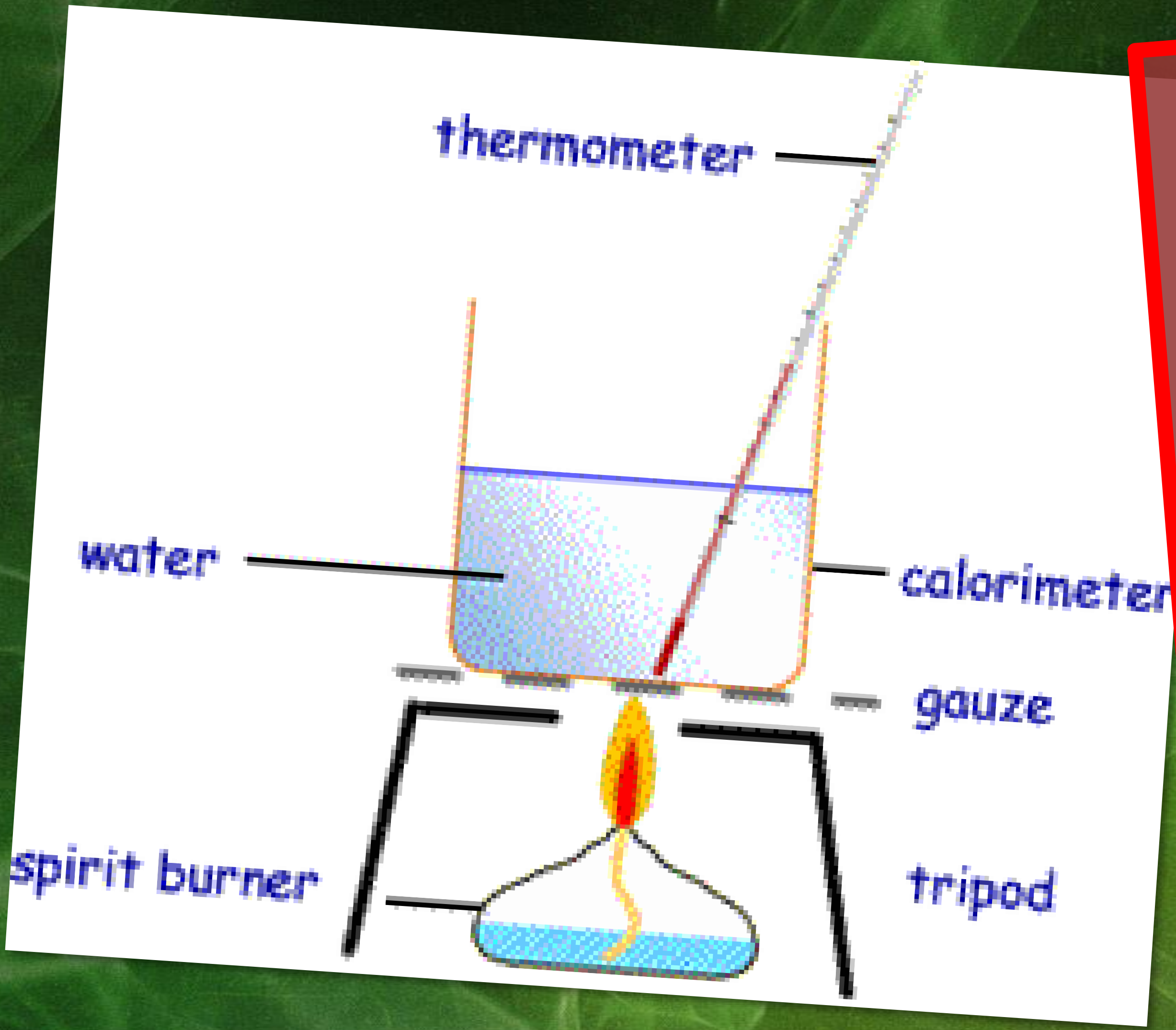
CALORIMETRY

SPECIFIC HEAT CAPACITY

Substance	Specific heat capacity J/kg/ºC
water	4181

Water has a **very high** specific heat capacity. This makes it useful for storing **heat energy**, and for transporting it around the home using central heating pipes.

CALORIMETRY

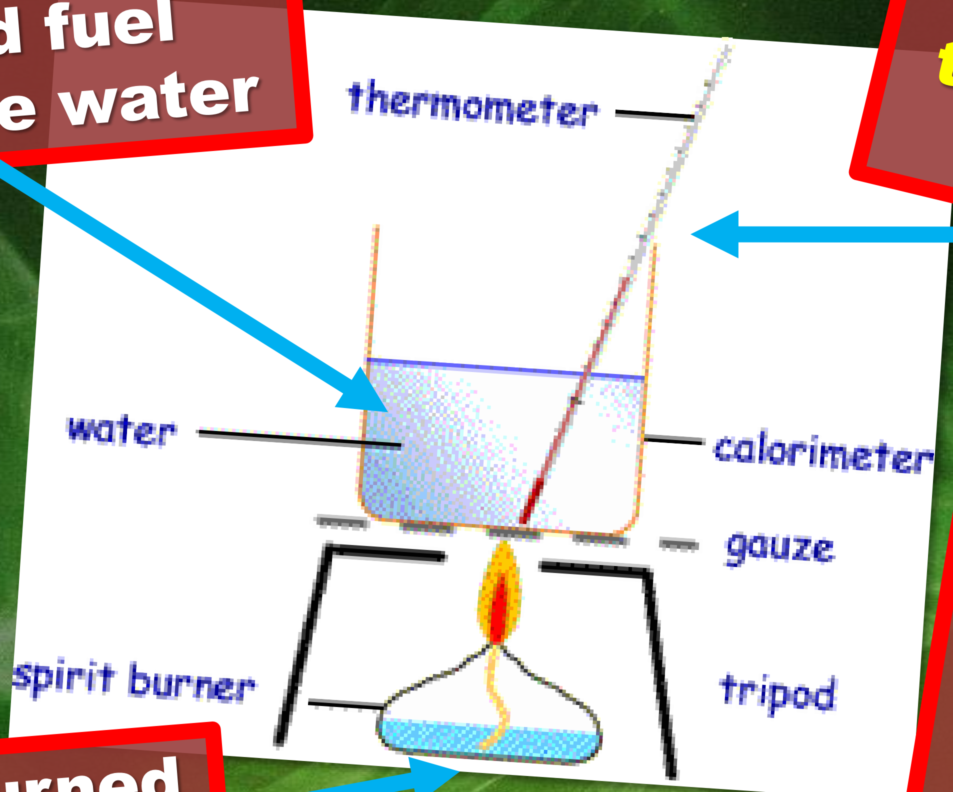


The energy released when a substance burns can be calculated based on the SPIRIT BURNER EXPERIMENT

CALORIMETRY

The **heat** from burned fuel **heats** the water

Thermometer reads the **temperature change**



The **mass** of the spirit burner is measured before and after.

Fuel is burned in spirit burner

CALORIMETRY

ENERGY EQUATION

To convert temperature rise into energy:

$$E_h = cm\Delta T$$

E_h **= the energy released**
c **= the specific heat capacity of water**
m **= the mass of water heated in kilograms**
($1000cm^3$ = 1litre = 1kg)
ΔT **= temperature change in °C**

CALORIMETRY

ENERGY EQUATION

$$E_h = cm\Delta T$$

SPECIFIC HEAT CAPACITY

water	4.18 $kJkg^{-1}{}^{o}C^{-1}$

CALORIMETRY

ENERGY EQUATION

$$E_h = cm\Delta T$$

SPECIFIC HEAT CAPACITY

water	4.18 $kJkg^{-1}{}^{o}C^{-1}$

To raise the temperature of 1kg of water by 1°C requires 4.18kJ

CALORIMETRY

ENERGY EQUATION

$$E_h = cm\Delta T$$

SPECIFIC HEAT CAPACITY

water	4.18 $kJkg^{-1}{}^{o}C^{-1}$

How much energy required to raise the temperature of 10kg of water by $1^{o}C$?

?

CALORIMETRY

ENERGY EQUATION

$$E_h = cm\Delta T$$

SPECIFIC HEAT CAPACITY

water	4.18 $kJkg^{-1}$ $°C^{-1}$

How much energy required to raise the temperature of 10kg of water by 1°C ?

41.8 $kJkg^{-1}$ $°C^{-1}$

CALORIMETRY

ENERGY EQUATION

$$E_h = cm\Delta T$$

SPECIFIC HEAT CAPACITY

water	4.18 $kJkg^{-1}\,^{o}C^{-1}$

How much energy required to raise the temperature of 1kg of water by 2°C ?

?

CALORIMETRY

ENERGY EQUATION

$$E_h = cm\Delta T$$

SPECIFIC HEAT CAPACITY

water	4.18 $kJkg^{-1}\,{}^{o}C^{-1}$

How much energy required to raise the temperature of 1kg of water by 2°C ?

2 x 4.18

= 8.36 $kJkg^{-1}\,{}^{o}C^{-1}$

CALORIMETRY

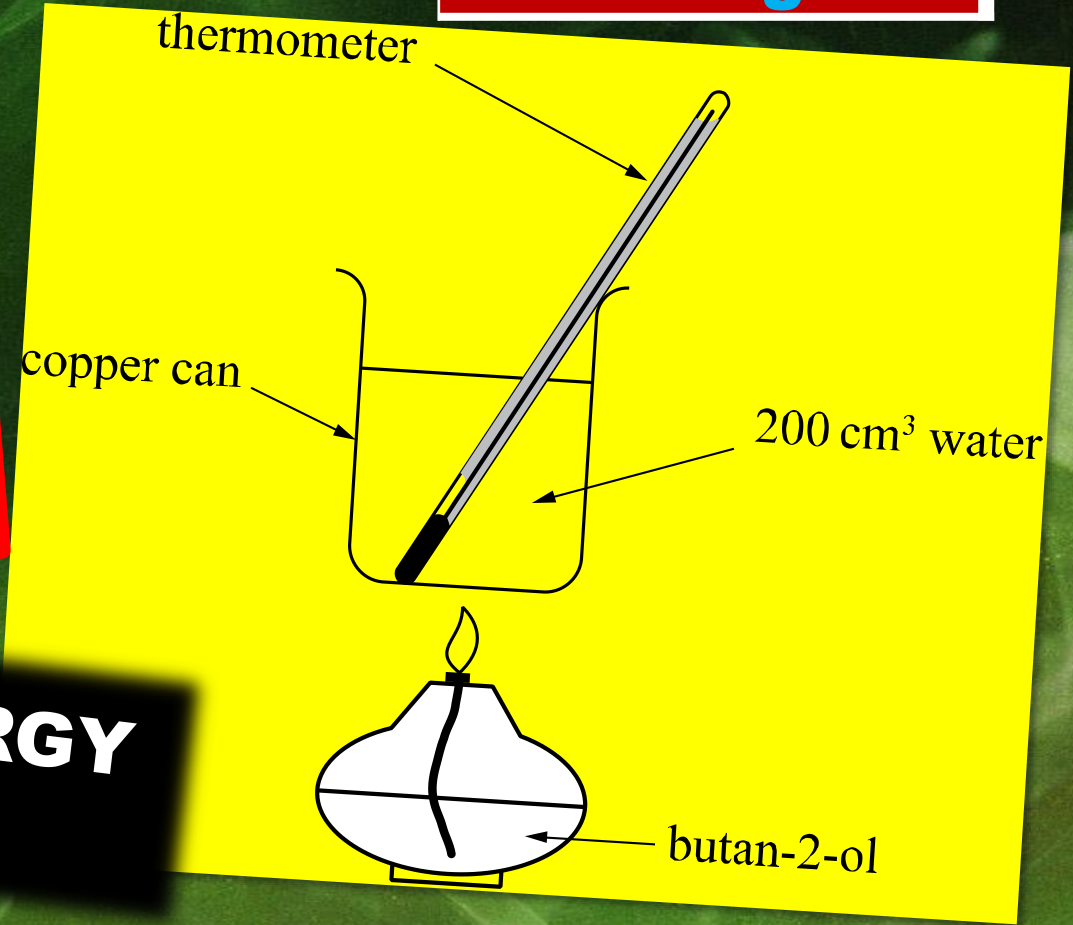
ENERGY EQUATION

$$E_h = cm\Delta T$$

4.18 kJkg^{-1}°C^{-1}

At the start of the experiment the temperature was 20°C.

At the end of the reaction temperature was 50°C.



CALCULATE ENERGY RELEASED?

CALORIMETRY

ENERGY EQUATION

$$E_h = cm\Delta T$$

4.18 $kJkg^{-1}\,^{o}C^{-1}$

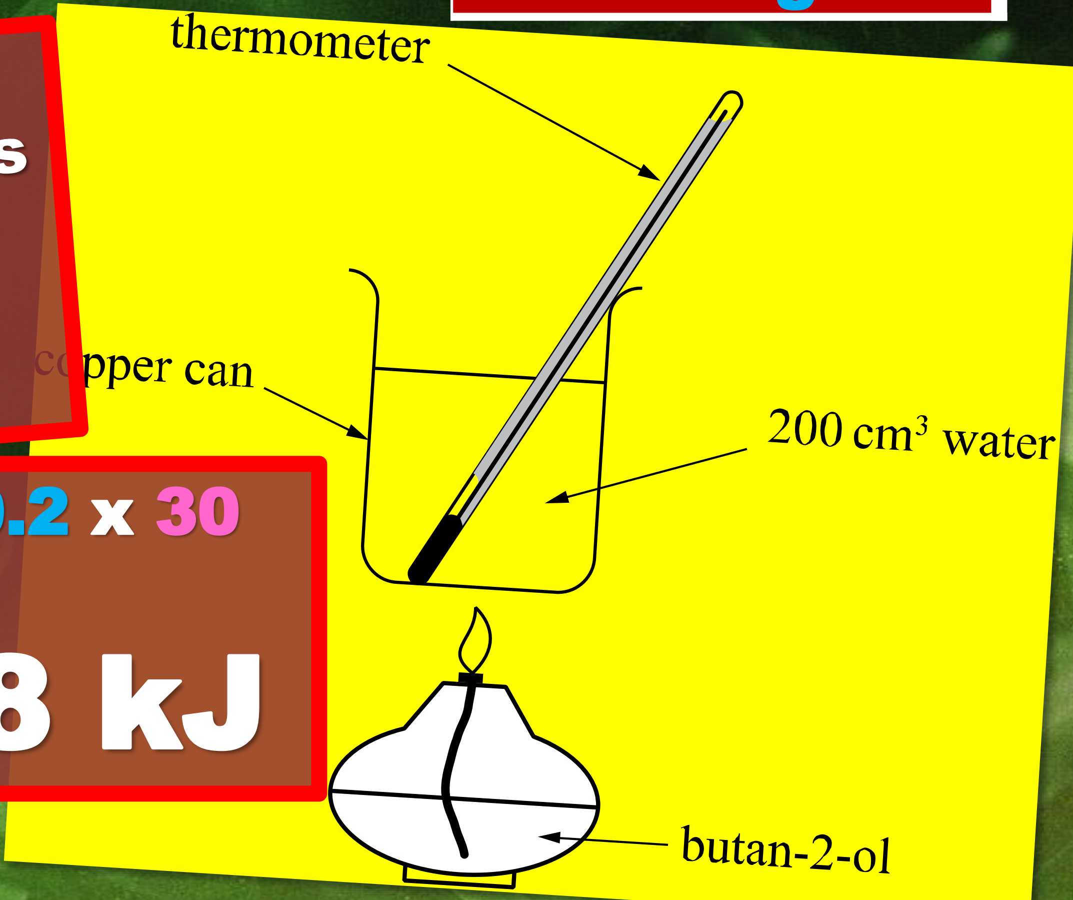
c = 4.18

m = 200cm³ (0.2 litres = 0.2kg)

ΔT = 50 °C – 20 °C = 30 °C

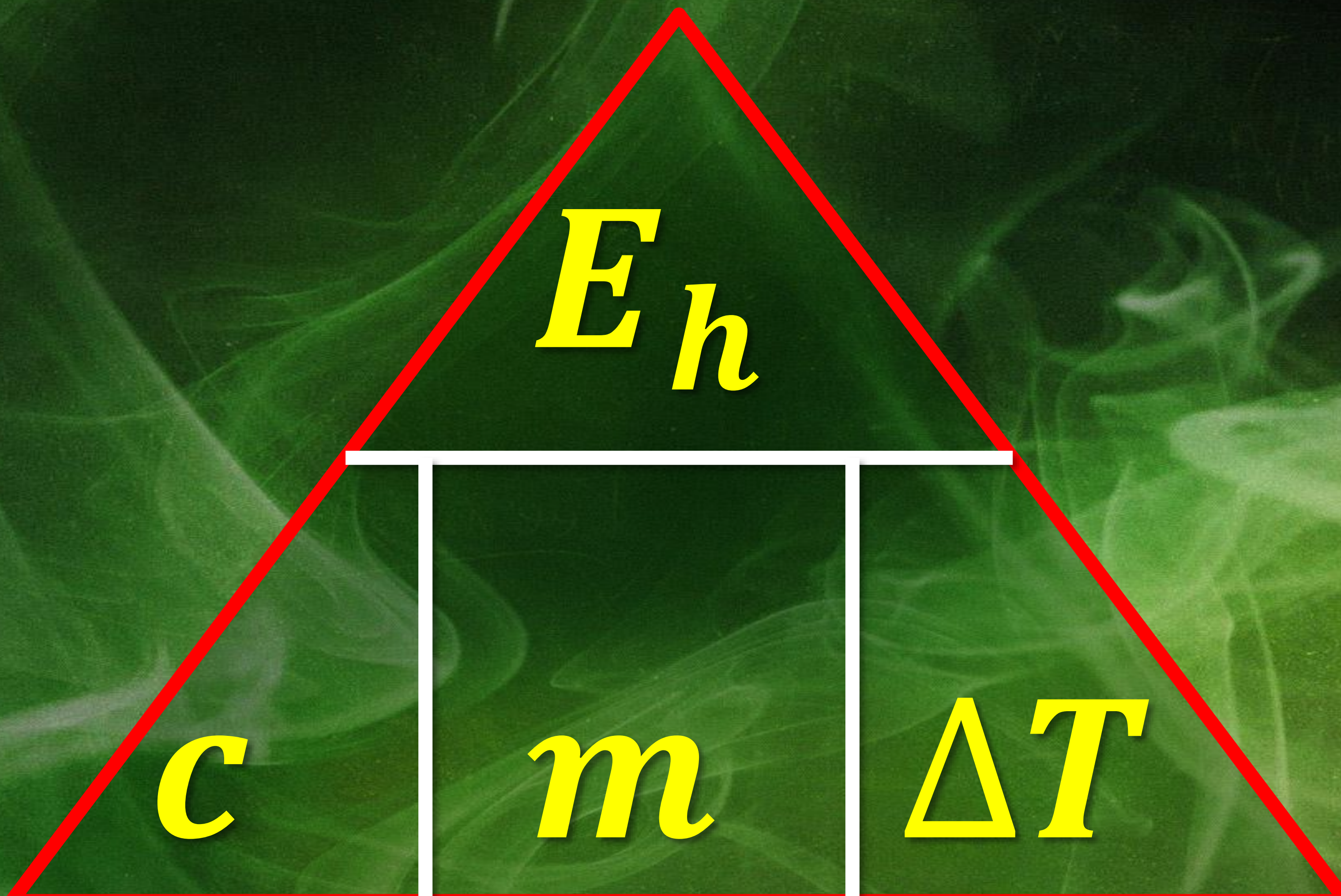
E_h = 4.18 x 0.2 x 30

= 25.08 kJ



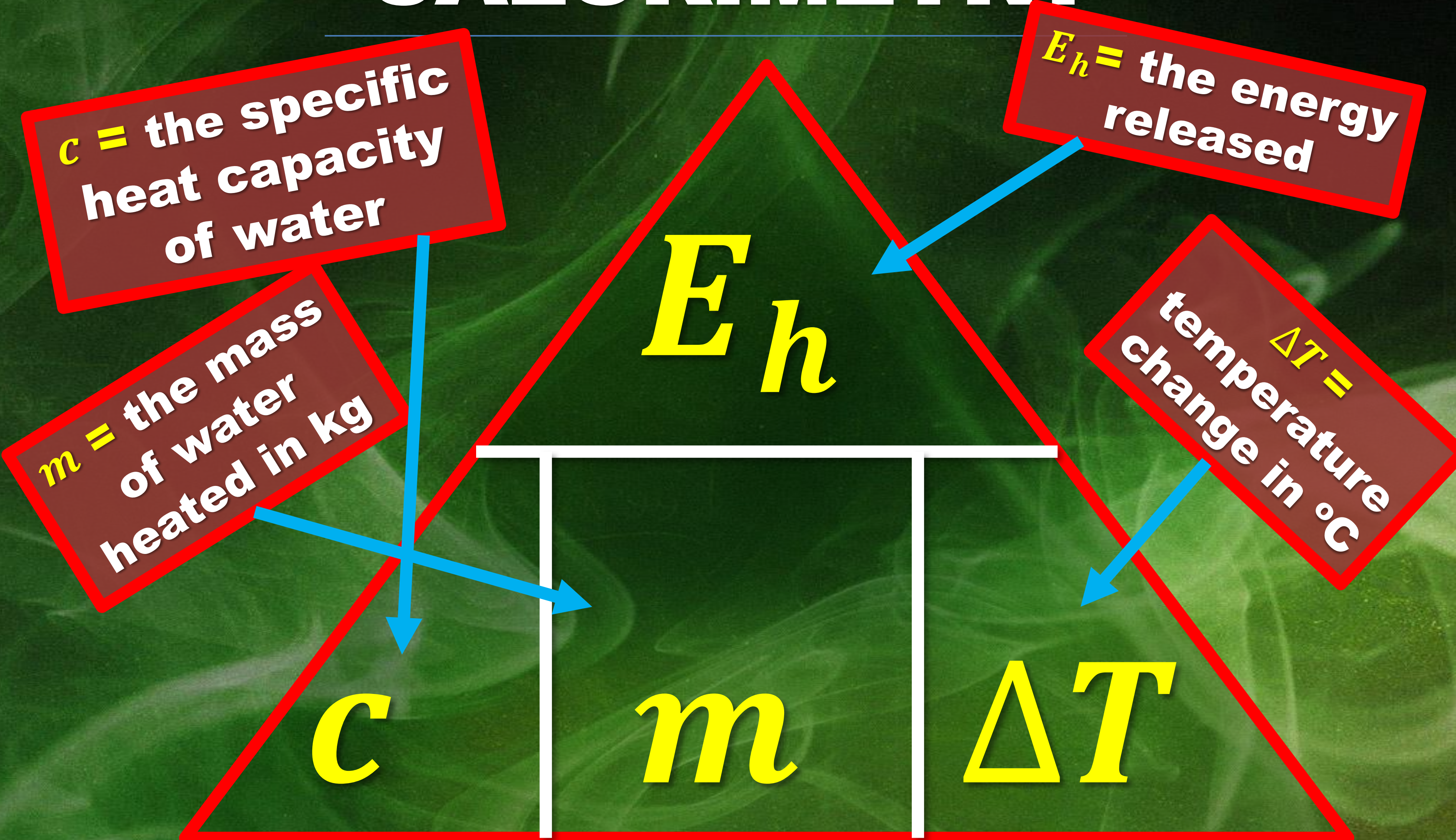
ENERGY EQUATION

CALORIMETRY



ENERGY EQUATION

CALORIMETRY



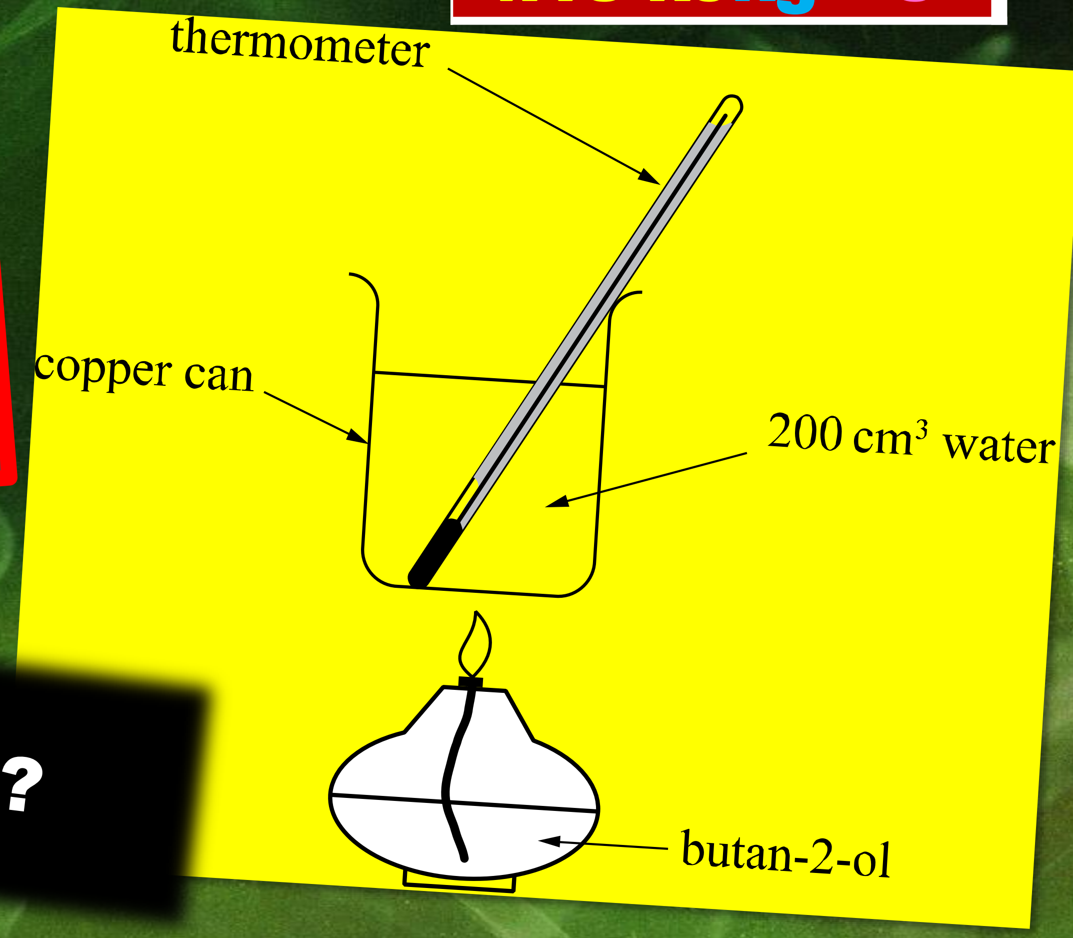
CALORIMETRY

ENERGY EQUATION

$$E_h = cm\Delta T$$

$4.18\ kJkg^{-1}{}^{o}C^{-1}$

The energy released from a system at 20^{o}C was 6.27kJ.
What was the final temperature?



TEMPERATURE?

CALORIMETRY

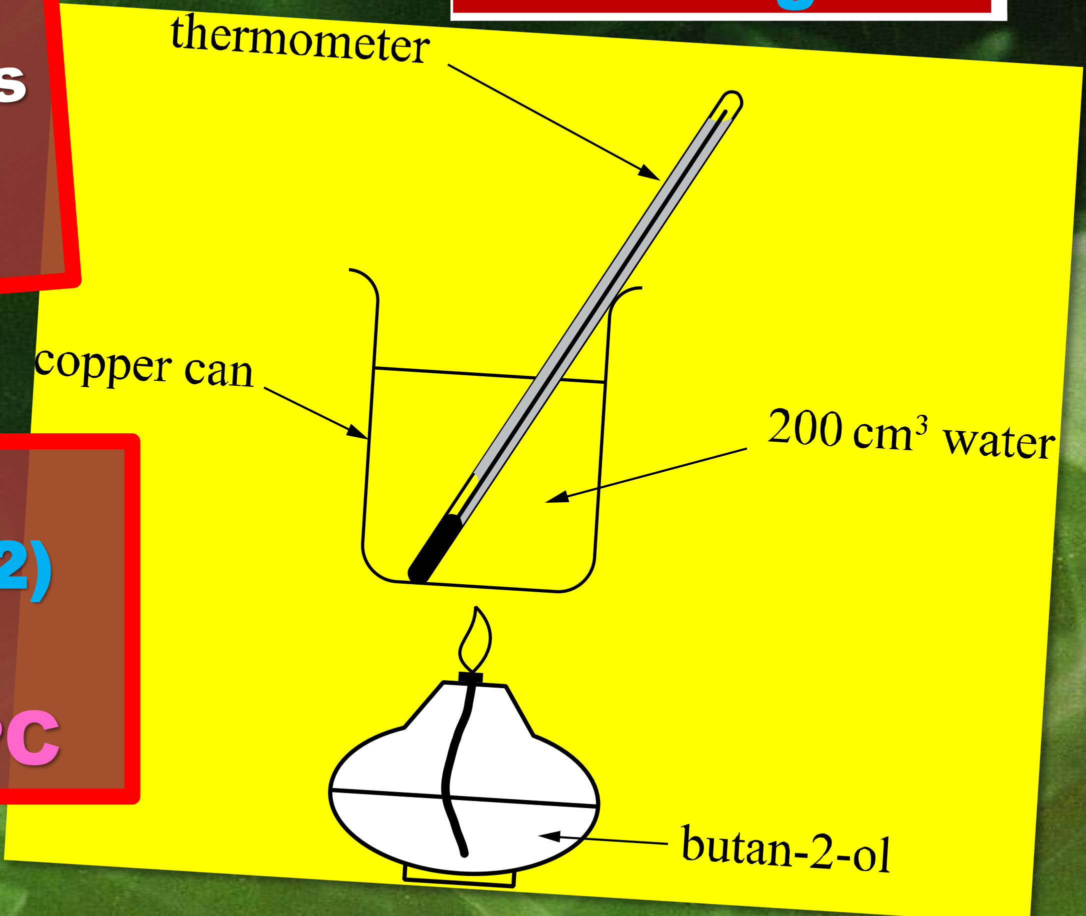
ENERGY EQUATION

$$E_h = cm\Delta T$$

4.18 $kJkg^{-1}°C^{-1}$

c = 4.18
m = 200cm^3 (0.2 litres = 0.2kg)
E_h = 6.27kJ

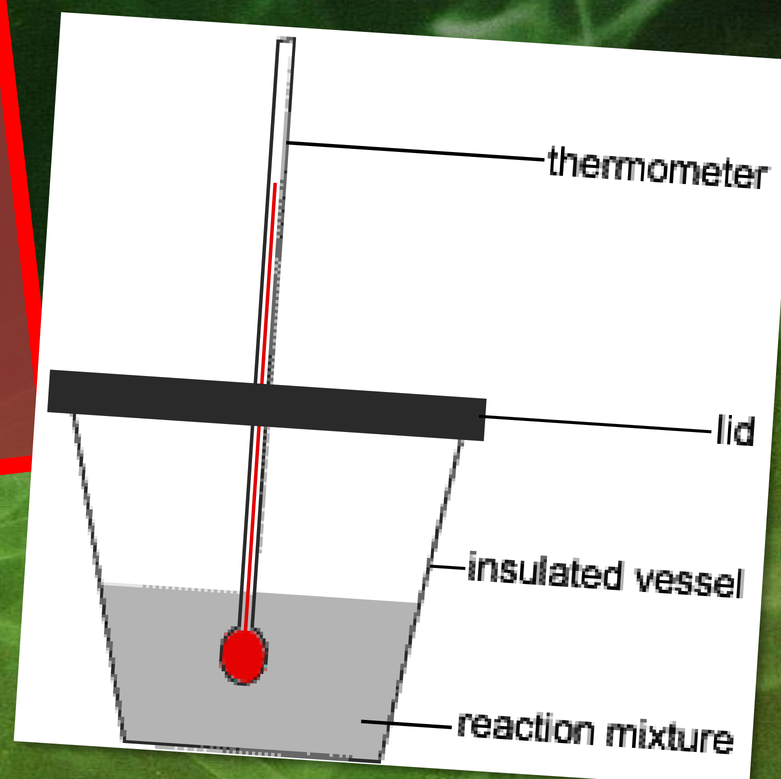
$\Delta T = E_h$ / (c X m)
= 6.27 / (4.18 X 0.2)
= 7.5 °C
20 + 7.5 = 27.5°C



CALORIMETRY

Enthalpy of solution

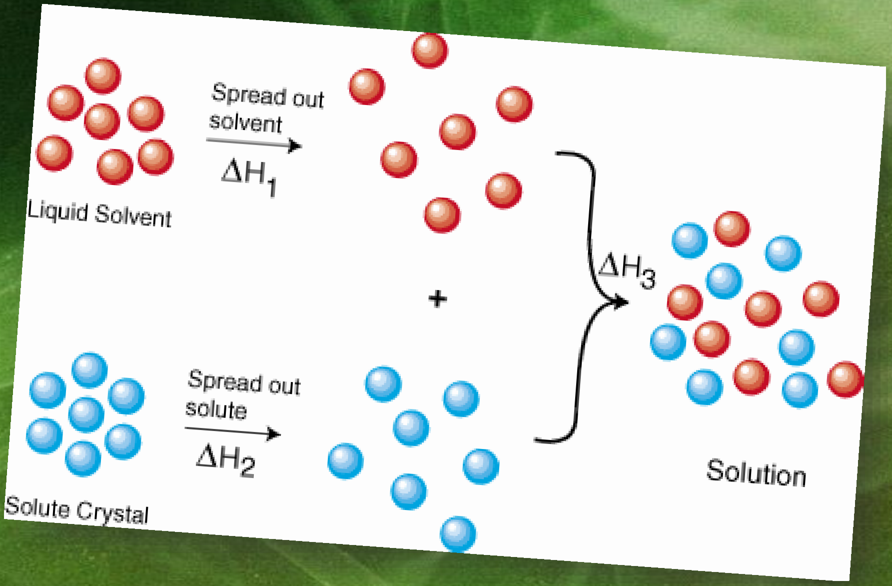
Enthalpy change associated with the dissolution of a substance in a solvent at constant pressure resulting in infinite dilution.



CALORIMETRY

Enthalpy of solution

The enthalpy change when 1mol of ionic compound fully dissolves in water.



CALORIMETRY

Enthalpy of solution

The enthalpy change when 1mol of ionic compound fully dissolves in water.

$$NaCl\,(s) \rightarrow Na^{+}(aq) + Cl^{-}(aq)$$

CALORIMETRY

Enthalpy of solution

The enthalpy change when 1mol of <u>ionic compound</u> fully dissolves in water.

$$NaCl\,(s) \rightarrow Na^{+}(aq) + Cl^{-}(aq)$$

CAN BE ENDO/EXOTHERMIC REACTION!

CALORIMETRY

Enthalpy of Hydration

The enthalpy change when 1mol of gaseous ions fully dissolves in water.

$$Na^{+}(g) \rightarrow Na^{+}(aq)$$

CALORIMETRY

Enthalpy of Hydration

The enthalpy change when 1mol of <u>gaseous ions</u> fully dissolves in water.

$$Na^{+}(g) \rightarrow Na^{+}(aq)$$

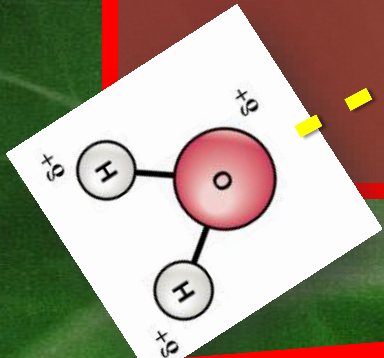
ALWAYS EXOTHERMIC REACTION!

CALORIMETRY

Enthalpy of Hydration

The enthalpy change when 1mol of <u>gaseous ions</u> fully dissolves in water.

$$Na^{+}(g) \rightarrow Na^{+}(aq)$$



Bond forming gives out energy

ALWAYS EXOTHERMIC REACTION!

CALORIMETRY

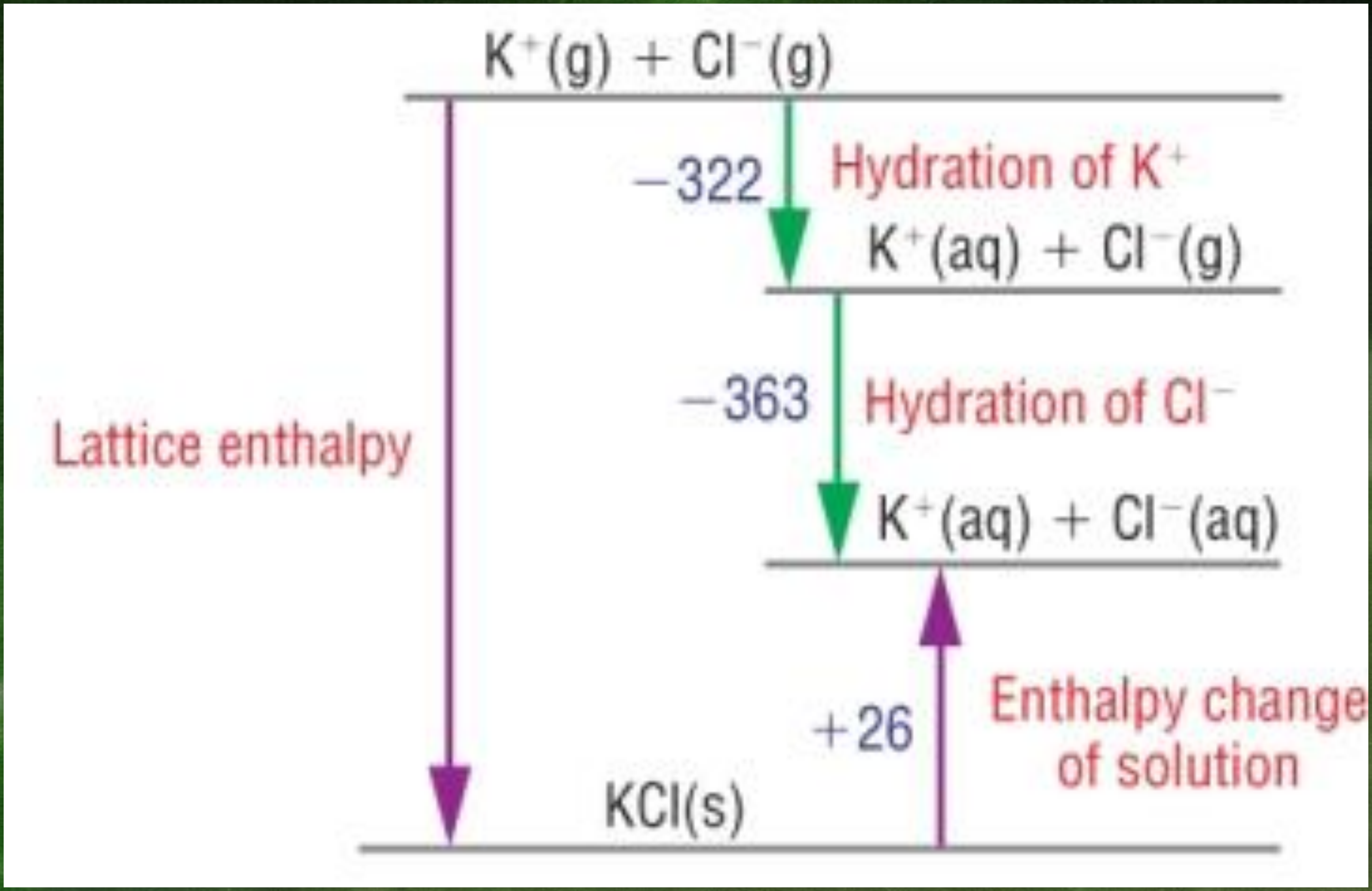
Lattice Enthalpy

The enthalpy change when 1mol of ionic lattice is formed from gaseous ions.

$$Na^{+}(g) + Cl^{-}(g) \rightarrow NaCl(s)$$

ALWAYS EXOTHERMIC REACTION!

CALORIMETRY



CALORIMETRY

Enthalpy of neutralisation

Enthalpy of neutralisation of an acid is the enthalpy change when the acid is neutralised to form 1mol of water.

$$H^+\,(aq) + OH^-\,(aq) \rightarrow H_2O\,(l)$$

CALORIMETRY

Enthalpy of neutralisation

Calculate the enthalpy of neutralisation of HCl(aq) by NaOH(aq)

$$NaOH + HCl \rightarrow NaCl + H_2O + \text{Heat}$$

Measurement	Results
Solutions used	20cm^3 2mol l^{-1} HCl 20cm^3 2mol l^{-1} NaOH
Temperature of acid before mixing	19.5°C
Temperature of alkali before mixing	18.5°C
Highest temperature of solution after mixing	32.5°C

Enthalpy of Neutralisation

Average initial temperature
= (19.5 + 18.5)/2 = 19°C

Temperature rise ΔT
= 32.5 – 19 = 13.5°C

Total volume of solution
= $40cm^3$

Mass of solution
= 40g = 0.04kg

Enthalpy of Neutralisation

Heat of energy released E_h

$= cm\Delta T$

$= 4.18 \times 0.04 \times 13.5 = 2.26kJ$

Number of moles of acid = cv

$= 2 \times 0.02 = 0.04$ moles

Number of moles of water formed

= 0.04

(since 1mole of HCl → 1mole of H_2O)

Enthalpy of Neutralisation

0.04moles of water → 2.26kJ

1 mole of water → 2.26/0.04
=56.4kJ

Enthalpy of Neutralisation, ΔH
= $-56.4\ kJmol^{-1}$

CHEMICAL ENERGY

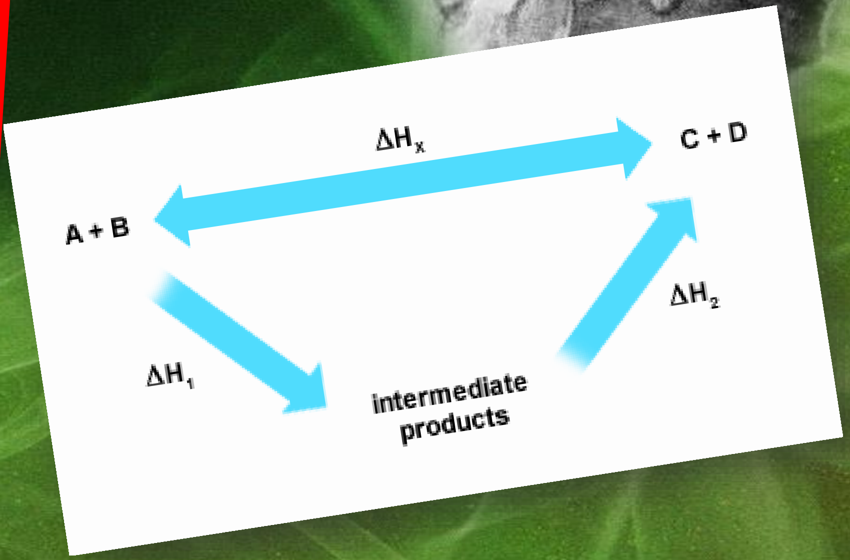
HESS'S LAW

The total enthalpy change for a reaction doesn't depend on the pathway it takes but only on its initial and final states.

CHEMICAL ENERGY

HESS'S LAW

As long as you start with the same reactant and end with the same products the enthalpy change will stay the same regardless of the reaction pathway.



CHEMICAL ENERGY

HESS'S LAW

STANDARD ENTHALPY OF FORMATION

(ΔH_f^o)

THE **AMOUNT OF HEAT** LOST OR GAINED WHEN **ONE MOLE OF A COMPOUND** IS FORMED FROM ITS CONSTITUENT ELEMENTS.

CHEMICAL ENERGY

HESS'S LAW

THE ENTHALPY CHANGE FOR A REACTION IS **EQUAL** TO THE SUM OF THE ENTHALPY OF FORMATION OF ALL THE PRODUCTS **MINUS** THE SUM OF THE ENTHALPY OF FORMATION OF ALL THE REACTANTS.

CHEMICAL ENERGY

HESS'S LAW

THE ENTHALPY CHANGE FOR A REACTION IS **EQUAL** TO THE SUM OF THE ENTHALPY OF FORMATION OF ALL THE PRODUCTS **MINUS** THE SUM OF THE ENTHALPY OF FORMATION OF ALL THE REACTANTS.

$$\Delta H^{o}_{reaction} = \sum n_p \Delta H^{o}_{f\,products} - \sum n_r \Delta H^{o}_{f\,reactants}$$

CHEMICAL ENERGY

HESS'S LAW

$$4\,Fe(s) + 3\,O_2(g) \longrightarrow 2\,Fe_2O_3(s)$$

Enthalpy of the reaction?

CHEMICAL ENERGY

HESS'S LAW

$$4\,Fe(s) + 3\,O_2(g) \longrightarrow 2\,Fe_2O_3(s)$$

$$\Delta H^\circ_{f\,Fe} = 0\ kJ/mol$$

$$\Delta H^\circ_{f\,O_2} = 0\ kJ/mol$$

$$\Delta H^\circ_{f\,Fe_2O_3} = -826\ kJ/mol$$

CHEMICAL ENERGY

HESS'S LAW

$$4\,Fe(s) + 3\,O_2(g) \longrightarrow 2\,Fe_2O_3(s)$$

$$\Delta H^\circ_{reaction} = [n_{Fe_2O_3} \cdot \Delta H^\circ_{f\,Fe_2O_3}] - [(n_{Fe} \cdot \Delta H^\circ_{f\,Fe}) + (n_{O_2} \cdot \Delta H^\circ_{f\,O_2})]$$

CHEMICAL ENERGY

HESS'S LAW

$$4\,Fe(s) + 3\,O_2(g) \longrightarrow 2\,Fe_2O_3(s)$$

$$\Delta H^{o}_{reaction} = \left[\,2\text{ mol} \cdot -826\,\frac{kJ}{mol}\,\right] - \left[\left(4\text{ mol} \cdot 0\,\frac{kJ}{mol}\right) + \left(3\text{ mol} \cdot 0\,\frac{kJ}{mol}\right)\right]$$

CHEMICAL ENERGY

HESS'S LAW

$$4\,Fe(s) + 3\,O_2(g) \longrightarrow 2\,Fe_2O_3(s)$$

$$\Delta H^{\circ}_{reaction} = -1652\ kJ$$

CHEMICAL ENERGY

HESS'S LAW

Calculate ΔH for the following reaction-

$$2CO_{(g)} + O_{2(g)} \longrightarrow 2CO_{2(g)} \quad \Delta H = ?$$

$$2C_{(s)} + O_{2(g)} \longrightarrow 2CO_{(g)} \quad \Delta H = -221.0\ kJ$$

$$C_{(s)} + O_{2(g)} \longrightarrow CO_{2(g)} \quad \Delta H = -393.5\ kJ$$

Step 1. Manipulate given equations to most closely resemble equation of interest

CHEMICAL ENERGY

HESS'S LAW

$$2CO_{(g)} + O_{2(g)} \longrightarrow 2CO_{2(g)} \quad \Delta H = ?$$

$$2C_{(s)} + O_{2(g)} \longrightarrow 2CO_{(g)} \quad \Delta H = -221.0 \text{ kJ}$$

Step 1. Manipulate given equations to most closely resemble equation of interest.

$$C_{(s)} + O_{2(g)} \longrightarrow CO_{2(g)} \quad \Delta H = -393.5 \text{ kJ}$$

Perform same "operation" on ΔH as on equation.

$$2CO_{(g)} \longrightarrow 2C_{(s)} + O_{2(g)} \quad \Delta H = +221.0 \text{ kJ}$$

If you "flip" equation, flip the sign on ΔH.

CHEMICAL ENERGY

HESS'S LAW

$$2CO_{(g)} + O_{2(g)} \longrightarrow 2CO_{2(g)} \quad \Delta H = ?$$

Put reactants on reactants side.

$$2C_{(s)} + O_{2(g)} \longrightarrow 2CO_{(g)} \quad \Delta H = -221.0\ kJ$$

$$C_{(s)} + O_{2(g)} \longrightarrow CO_{2(g)} \quad \Delta H = -393.5\ kJ$$

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CHEMICAL ENERGY

HESS'S LAW

$$2CO_{(g)} + O_{2(g)} \longrightarrow 2CO_{2(g)} \quad \Delta H = ?$$

$$2C_{(s)} + O_{2(g)} \longrightarrow 2CO_{(g)} \quad \Delta H = -221.0\ kJ$$

$$2\left[C_{(s)} + O_{2(g)} \longrightarrow CO_{2(g)} \quad \Delta H = -393.5\ kJ\right]$$

Step 1. Manipulate given equations to most closely resemble equation of interest.

Perform same "operation" on ΔH as on equation.

$$2CO_{(g)} \longrightarrow 2C_{(s)} + O_{2(g)} \quad \Delta H = +221.0\ kJ$$

$$2C_{(s)} + 2O_{2(g)} \longrightarrow 2CO_{2(g)} \quad \Delta H = -787\ kJ$$

If you multiply or divide the chemical equation, multiply or divide ΔH by the same number.

CHEMICAL ENERGY

HESS'S LAW

$$2CO_{(g)} + O_{2(g)} \longrightarrow 2CO_{2(g)} \quad \Delta H = ?$$

Need to sort the moles of product.

$$2C_{(s)} + O_{2(g)} \longrightarrow 2CO_{(g)} \quad \Delta H = -221.0 \text{ kJ}$$

$$2\left[C_{(s)} + O_{2(g)} \longrightarrow CO_{2(g)} \quad \Delta H = -393.5 \text{ kJ}\right]$$

Step 1. Manipulate given equations to most closely resemble equation of interest.

Perform same "operation" on ΔH as on equation.

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If you multiply or divide the chemical equation, multiply or divide ΔH by the same number.

CHEMICAL ENERGY

HESS'S LAW

$$2CO_{(g)} + O_{2(g)} \longrightarrow 2CO_{2(g)} \quad \Delta H = ?$$

Step 2. Add "new" reactions together.

$$2CO_{(g)} \longrightarrow 2C_{(s)} + O_{2(g)} \quad \Delta H = +221.0 \text{ kJ}$$

$$+ \quad 2C_{(s)} + 2O_{2(g)} \longrightarrow 2CO_{2(g)} \quad \Delta H = -787 \text{ kJ}$$

$$2CO_{(g)} + 2C_{(s)} + 2O_{2(g)} \longrightarrow 2C_{(s)} + O_{2(g)} + 2CO_{2(g)} \quad \Delta H = -566 \text{ kJ}$$

CHEMICAL ENERGY

HESS'S LAW

$$2CO_{(g)} + O_{2(g)} \longrightarrow 2CO_{2(g)} \quad \Delta H = ?$$

Step 3. Cancel out any compounds that are the same on both sides of the reaction arrow.

$$2CO_{(g)} \longrightarrow 2C_{(s)} + O_{2(g)} \quad \Delta H = +221.0\ kJ$$

$$+ \quad 2C_{(s)} + 2O_{2(g)} \longrightarrow 2CO_{2(g)} \quad \Delta H = -787\ kJ$$

$$2CO_{(g)} + \cancel{2C}_{(s)} + 1O_{2(g)} \longrightarrow \cancel{2C}_{(s)} + \cancel{O}_{2(g)} + 2CO_{2(g)} \quad \Delta H = -566\ kJ$$

CHEMICAL ENERGY

HESS'S LAW

$$2CO_{(g)} + O_{2(g)} \longrightarrow 2CO_{2(g)} \quad \Delta H = ?$$

Step 4. Write new equation and double check to make sure it matches the equation of interest.

$$2CO_{(g)} \longrightarrow 2C_{(s)} + O_{2(g)} \quad \Delta H = +221.0 \text{ kJ}$$

$$+ \quad 2C_{(s)} + 2O_{2(g)} \longrightarrow 2CO_{2(g)} \quad \Delta H = -787 \text{ kJ}$$

$$2CO_{(g)} + O_{2(g)} \longrightarrow 2CO_{2(g)} \quad \Delta H = -566 \text{ kJ}$$

CHEMICAL ENERGY

HESS'S LAW

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CHEMICAL ENERGY

HESS'S LAW

?

Calculate ΔH for the following reaction-

$$2N_{2(g)} + 5O_{2(g)} \longrightarrow 2N_2O_{5(g)} \qquad \Delta H = ?$$

$$H_{2(g)} + \tfrac{1}{2}O_{2(g)} \longrightarrow H_2O_{(l)} \qquad \Delta H = -285.8\ kJ$$

$$N_2O_{5(g)} + H_2O_{(l)} \longrightarrow 2HNO_{3(l)} \qquad \Delta H = -76.6\ kJ$$

$$N_{2(g)} + 3O_{2(g)} + H_{2(g)} \longrightarrow 2HNO_{3(l)} \qquad \Delta H = -348.2\ kJ$$

CHEMICAL ENERGY

HESS'S LAW

Flip equation and multiply by 2.

Calculate ΔH for the following reaction-

$$2N_{2(g)} + 5O_{2(g)} \longrightarrow 2N_2O_{5(g)} \qquad \Delta H = ?$$

$$H_{2(g)} + ½O_{2(g)} \longrightarrow H_2O_{(l)} \qquad \Delta H = -285.8 \text{ kJ}$$

$$2\left(\boxed{N_2O_{5(g)} + H_2O_{(l)} \longrightarrow 2HNO_{3(l)} \qquad \Delta H = -76.6 \text{ kJ}}\right)$$

$$N_{2(g)} + 3O_{2(g)} + H_{2(g)} \longrightarrow 2HNO_{3(l)} \qquad \Delta H = -348.2 \text{ kJ}$$

CHEMICAL ENERGY

HESS'S LAW

Calculate ΔH for the following reaction-

Multiply by 2 so the reactants match

$$2N_{2(g)} + 5O_{2(g)} \longrightarrow 2N_2O_{5(g)} \qquad \Delta H = ?$$

$$H_{2(g)} + \tfrac{1}{2}O_{2(g)} \longrightarrow H_2O_{(l)} \qquad \Delta H = -285.8\ kJ$$

$$N_2O_{5(g)} + H_2O_{(l)} \longrightarrow 2HNO_{3(l)} \qquad \Delta H = -76.6\ kJ$$

$$2\left(\boxed{N_{2(g)} + 3O_{2(g)} + H_{2(g)} \longrightarrow 2HNO_{3(l)} \qquad \Delta H = -348.2\ kJ}\right)$$

CHEMICAL ENERGY

HESS'S LAW

$2N_{2(g)} + 5O_{2(g)} \longrightarrow 2N_2O_{5(g)}$

Need to get rid of H_2O from product side.

$H_{2(g)} + ½O_{2(g)} \longrightarrow H_2O_{(l)}$ $\Delta H = -285.8\ kJ$

$N_2O_{5(g)} + H_2O_{(l)} \longrightarrow 2HNO_{3(l)}$ $\Delta H = -76.6\ kJ$

$N_{2(g)} + 3O_{2(g)} + H_{2(g)} \longrightarrow 2HNO_{3(l)}$ $\Delta H = -348.2\ kJ$

$4HNO_{3(l)} \longrightarrow 2N_2O_{5(g)} + 2H_2O_{(l)}$ $\Delta H = 153\ kJ$

$2N_{2(g)} + 6O_{2(g)} + 2H_{2(g)} \longrightarrow 4HNO_{3(l)}$ $\Delta H = -696\ kJ$

$H_{2(g)} + ½O_{2(g)} \longrightarrow H_2O_{(l)}$ $\Delta H = -285.8\ kJ$

CHEMICAL ENERGY

HESS'S LAW

$$2N_{2(g)} + 5O_{2(g)} \longrightarrow 2N_2O_{5(g)} \quad \Delta H$$

Flip equation and multiply by 2.

$$H_{2(g)} + \tfrac{1}{2}O_{2(g)} \longrightarrow H_2O_{(l)} \quad \Delta H = -285.8\ kJ$$

$$N_2O_{5(g)} + H_2O_{(l)} \longrightarrow 2HNO_{3(l)} \quad \Delta H = -76.6\ kJ$$

$$N_{2(g)} + 3O_{2(g)} + H_{2(g)} \longrightarrow 2HNO_{3(l)} \quad \Delta H = -348.2\ kJ$$

$$4HNO_{3(l)} \longrightarrow 2N_2O_{5(g)} + 2H_2O_{(l)} \quad \Delta H = 153\ kJ$$

$$2N_{2(g)} + 6O_{2(g)} + 2H_{2(g)} \longrightarrow 4HNO_{3(l)} \quad \Delta H = -696\ kJ$$

$$\boxed{H_{2(g)} + \tfrac{1}{2}O_{2(g)} \longrightarrow H_2O_{(l)} \quad \Delta H = -285.8\ kJ}$$

CHEMICAL ENERGY

HESS'S LAW

$$2N_{2(g)} + 5O_{2(g)} \longrightarrow 2N_2O_{5(g)} \qquad \Delta H = ?$$

$$H_{2(g)} + \tfrac{1}{2}O_{2(g)} \longrightarrow H_2O_{(l)} \qquad \Delta H = -285.8\ kJ$$

$$N_2O_{5(g)} + H_2O_{(l)} \longrightarrow 2HNO_{3(l)} \qquad \Delta H = -76.6\ kJ$$

$$N_{2(g)} + 3O_{2(g)} + H_{2(g)} \longrightarrow 2HNO_{3(l)} \qquad \Delta H = -348.2\ kJ$$

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$$2N_{2(g)} + 6O_{2(g)} + 2H_{2(g)} \longrightarrow 4HNO_{3(l)} \qquad \Delta H = -696\ kJ$$

$$2\left(H_2O_{(l)} \longrightarrow H_{2(g)} + \tfrac{1}{2}O_{2(g)}\right) \qquad \Delta H = (+285.8\ kJ)\times 2$$

CHEMICAL ENERGY

HESS'S LAW

Cancel everything that balances on either side of the arrow.

$$2N_{2(g)} + 5O_{2(g)} \longrightarrow 2N_2O_{5(g)}$$

$$\cancel{4HNO_{3(l)}} \longrightarrow 2N_2O_{5(g)} + \cancel{2H_2O_{(l)}} \qquad \Delta H = 153\ kJ$$

$$2N_{2(g)} + 6O_{2(g)} + \cancel{2H_{2(g)}} \longrightarrow \cancel{4HNO_{3(l)}} \qquad \Delta H = -696\ kJ$$

$$\cancel{2H_2O_{(l)}} \longrightarrow \cancel{2H_{2(g)}} + \cancel{O_{2(g)}} \qquad \Delta H = 572\ kJ$$

+

$$2N_{2(g)} + 5O_{2(g)} \longrightarrow 2N_2O_{5(g)} \qquad \Delta H = 29\ kJ$$

CHEMICAL ENERGY

HESS'S LAW

Then combine equations to get ΔH of desired reaction.
153+(-696)+572
= <u>29 kJ</u>

$$2N_{2(g)} + 5O_{2(g)} \longrightarrow 2N_2O_{5(g)}$$

$$\cancel{4HNO_{3(l)}} \longrightarrow 2N_2O_{5(g)} + \cancel{2H_2O_{(l)}} \qquad \Delta H = 153\ kJ$$

$$2N_{2(g)} + 6O_{2(g)} + \cancel{2H_{2(g)}} \longrightarrow \cancel{4HNO_{3(l)}} \qquad \Delta H = -696\ kJ$$

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+

$$2N_{2(g)} + 5O_{2(g)} \longrightarrow 2N_2O_{5(g)} \qquad \boxed{\Delta H = 29\ kJ}$$

CHEMICAL ENERGY

HESS'S LAW

Bond Enthalpy

Enthalpy change when a bond in gaseous molecule is broken.

$$Cl_2\ (g) \rightarrow 2Cl\ (g)$$

$$\Delta H = 243\ kJmol^{-1}$$

CHEMICAL ENERGY

HESS'S LAW

Bond Enthalpy

Cl_2 (g) $\rightarrow$ 2Cl (g)

$\Delta H = 243\ kJmol^{-1}$

It takes 243kJ of energy to break the bonds between all the Cl molecules.

Breaking bonds requires energy and is therefore **ENDOTHERMIC**

CHEMICAL ENERGY

HESS'S LAW

Bond Enthalpy

Cl_2 (g) → 2Cl (g)

$\Delta H = 243\ kJmol^{-1}$

It takes 243kJ of energy to break the bonds between all the Cl molecules.

Making bonds releases energy and is therefore **EXOTHERMIC**

CHEMICAL ENERGY

HESS'S LAW

Bond Enthalpy

ΔH?

$$H_2\ (g) + Cl_2\ (g) \rightarrow 2HCl\ (g)$$

Broken bonds	ΔH /$kJmol^{-1}$
H-H	432
Cl-Cl	243
Total	675

CHEMICAL ENERGY

HESS'S LAW

Bond Enthalpy

ΔH?

$$H_2\,(g) + Cl_2\,(g) \rightarrow 2HCl\,(g)$$

Broken made	ΔH /kJmol^{-1}
H-Cl	-432

CHEMICAL ENERGY

HESS'S LAW

Bond Enthalpy

ΔH?

$$H_2\,(g) + Cl_2\,(g) \rightarrow 2HCl\,(g)$$

1. Determine the number and type of bonds **BROKEN**
2. Determine the number and type of bonds **FORMED**

CHEMICAL ENERGY

HESS'S LAW

Bond Enthalpy

ΔH?

$$H_2\ (g) + Cl_2\ (g) \rightarrow 2HCl\ (g)$$

Broken made	ΔH /kJmol^{-1}
H-Cl	-432

Two bonds are being FORMED here

CHEMICAL ENERGY

HESS'S LAW

Bond Enthalpy

ΔH?

$$H_2\,(g) + Cl_2\,(g) \rightarrow 2HCl\,(g)$$

ΔH = total bonds broken + total bonds made

= 675 + (-864) = -189kJmol^{-1}

QUESTIONS

$Cl_{2\ (g)} + H_2O_{\ (l)} \leftrightarrow Cl^-_{\ (aq)} + ClO^-_{\ (aq)} + 2H^+_{\ (aq)}$

Which of the following is least likely to alter the position of equilibrium?

a) NaOH (aq)
b) NaBr (s)
c) HCl (aq)
d) KCl (s)

QUESTIONS

$$Cl_{2\,(g)} + H_2O_{(l)} \leftrightarrow Cl^-_{(aq)} + ClO^-_{(aq)} + 2H^+_{(aq)}$$

Which of the following is least likely to alter the position of equilibrium?

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QUESTIONS

Using enthalpies of formation (ethyne)

ΔH?

$$3C_2H_2\ (g) \rightarrow C_6H_6\ (l)$$

a) $\Delta H = 107\ kJmol^{-1}$

b) $\Delta H = +632\ kJmol^{-1}$

c) $\Delta H = -632\ kJmol^{-1}$

d) $\Delta H = -204\ kJmol^{-1}$

QUESTIONS

Using enthalpies of formation (ethyne)

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