St Ninian's High School

Chemistry Department

National 5 Chemistry

Unit 2: Nature's Chemistry

Topic 3

Energy From Fuels

Summary Notes

Name ____

Learning Outcomes

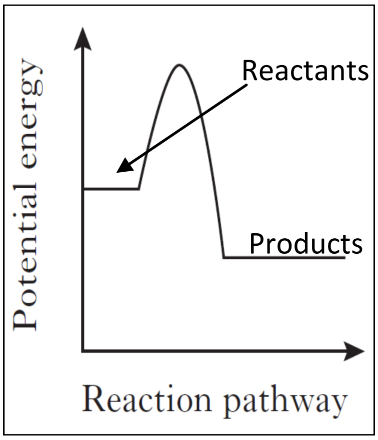
After completing this topic you should be able to :

1	state that a fuel is a chemical which burns to release energy
2	state that combustion is another word for burning
3	state that combustion is an exothermic reaction
4	state that when a substance burns it reacts with oxygen
5	state that alkanes and alcohols can be used as fuels
6	balance chemical equations for combustion reactions
7	calculate the quantity of heat released when a fuel burns using the relationship $E_h = cm\Delta T$
8	calculate the quantities of reactants and products in combustion reactions.

Fuels

A Source of Energy

A **fuel** is a substance that burns to release energy. Much of our energy comes from burning fuels, e.g. wood was one of the first fuels used by humans. The **burning** of a fuel is a chemical reaction in which the fuel reacts with oxygen to make new substances. **Combustion** is another word for burning. Combustion is an exothermic process since energy is released. The following graph illustrates how the energy of the products compares to the energy of the reactants.



The energy of the products is less than the reactants since energy is released overall in an exothermic reaction.

Fossil fuels are fuels which were formed from the remains of living things. Coal, oil, natural gas and peat are all examples of fossil fuels. The energy in fossil fuels can be traced back to the sun. It is stored in plants during photosynthesis where water and carbon dioxide are converted into glucose and oxygen.

Fuels

Photosynthesis Water + Carbon Dioxide → Glucose + Oxygen

$$H_2O + CO_2 \longrightarrow C_6H_{12}O_6 + O_2$$

The burning of fossil fuels releases the sun's energy from plants and animals that were living many millions of years ago. Fossil fuels are mainly hydrocarbons with minor impurities. Burning fossil fuels in a plentiful supply of air will therefore produce carbon dioxide and water (complete combustion - see Unit 2 Topic 1). Since there is a limited amount of fossil fuels they will run out and are classified as **finite.**

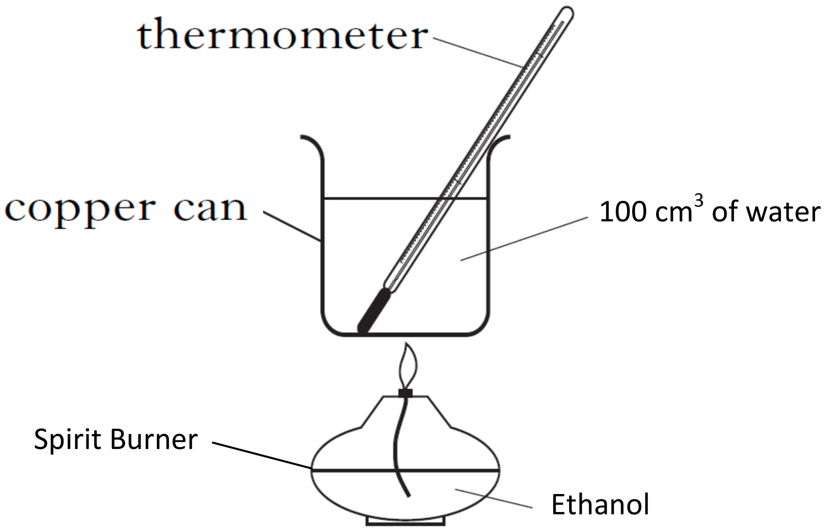
Alcohols as Fuels

In Unit 2 Topic 2 you learned that alcohols are used as fuels. Many modern cars are able to run on an ethanol/petrol mix. Ethanol can be made by the fermentation of glucose obtained from plants and is therefore renewable unlike petrol since it comes from oil which is finite.

Methanol is used as a fuel in some racing cars. It is regarded as safer than petrol. A methanol fire can be extinguished with water, whereas a petrol-based fire cannot. Different fuels release different quantities of heat energy per gram of fuel burned. The heat energy released when a fuel such as ethanol burns can be determined from experimental data.

Burning Ethanol

Apparatus



Results Table

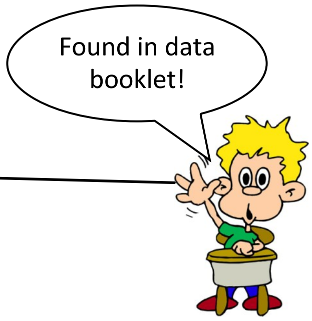
Mass of burner before burning	
Mass of burner after burning	
Mass of ethanol burned	
Initial temperature of water	
Highest temperature of water	
Temperature change of water	
Volume of water	

Fuels

Part 1: Determine the heat absorbed by the water.

The following relationship allows the heat absorbed to be calculated:

$$E_h = cm\Delta T$$



Where E_h = Energy gained by the water in kJ

c = Specific heat capacity of water = 4·18 kJ $kg^{-1}\,{}^{o}C^{-1}$ (This is a constant value for water)

m = Mass of water being heated (1 litre = 1 kg)

ΔT = Change in temperature of water

so Heat energy = specific heat capacity x mass of liquid x temperature change

Example: Volume of water = 200 cm^3 so m = 0·2 kg

ΔT = 20°C

Therefore:

$E_h = cm\Delta T$

E_h = 4·18 x 0·2 x 20 = 16·7 kJ

Part 2: Determine the heat released per gram of fuel burned.

Example: 0·85 grams of fuel burned to release 16·7 kJ of heat energy.

0·85 g ⟷ 16·7 kJ

$\frac{0{\cdot}85 \text{ g}}{0{\cdot}85}$ ⟷ $\frac{16{\cdot}7 \text{ kJ}}{0{\cdot}85}$

1 g ⟷ 19·6 kJ So the heat released per gram is 19·6 kJ. (19·6 kJ g^{-1})

Combustion Equations

Chemical equations tell us what substances are reacting and what substances are produced. A balanced chemical equation indicates the mole ratio in which the substances react or in which they are produced. This allows chemists to determine the actual quantities of chemicals required in a reaction and how much will be produced.

The following two examples illustrate how a balanced chemical equation can be used to determine quantities of reactants or products in combustion reactions.

Example 1: Ethanol (C_2H_5OH) burns in oxygen to produce carbon dioxide and water:

$$C_2H_5OH \quad + \quad 3O_2 \longrightarrow 2CO_2 \quad + \quad 3H_2O$$

Calculate the mass of carbon dioxide produced when 11·5 g of ethanol is burned in excess (extra) oxygen.

Step 1: Mole ratio

Ethanol ⟷ Carbon dioxide

1 mole ⟷ 2 moles

Step 2: Mass ratio

1 mole ⟷ 2 moles

46 g ⟷ 88 g (2 x 44)

Step 3: Find the mass produced when 1 g burns

$\frac{46}{46}$ g ⟷ $\frac{88}{46}$ g

1 g ⟷ $\frac{88}{46}$ g

Step 4: Change the mass to 11·5 g and solve.

11·5 g ⟷ $\frac{88}{46}$ x 11·5 g

11·5 g ⟷ 22 g Answer = 22 g

Example 2: Calculate the mass of methanol that would burn completely to give 110 g of carbon dioxide.

$2CH_3OH + 3O_2 \longrightarrow 2CO_2 + 4H_2O$

Step 1: Mole ratio

Methanol ⟷ Carbon Dioxide

2 moles ⟷ 2 moles

1 mole ⟷ 1 mole

Step 2: Mass ratio

1 mole ⟷ 1 mole

32 g ⟷ 44 g

Step 3: Find the mass needed to produced 1 g of carbon dioxide

$\frac{32}{44}$ g ⟷ $\frac{44}{44}$ g

$\frac{32}{44}$ g ⟷ 1 g

Step 4: Change the mass produced to 110 g and solve.

$\frac{32}{44}$ x 110 g ⟷ 1 x 110 g

80 g ⟷ 110 g Answer = 80 g

For more examples of calculations based on balanced equations refer to Unit 1 Topic 7.

Topic 3 Summary Statements

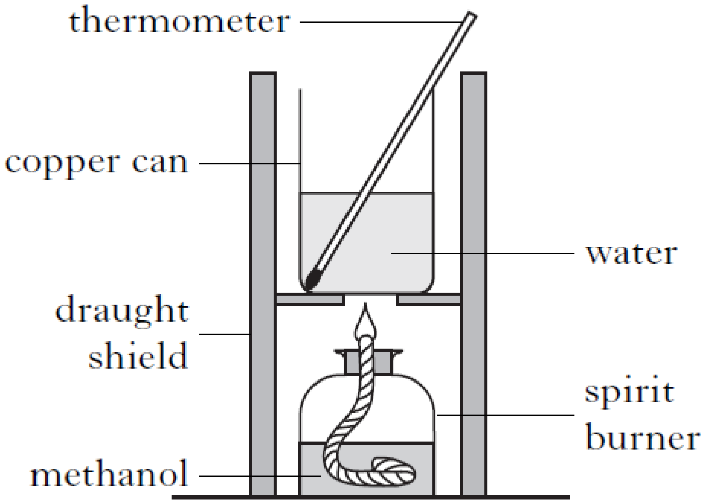
- [ ] A fuel is a chemical which burns to release energy.
- [ ] Burning is another word for combustion.
- [ ] Combustion reactions are exothermic since energy is released.
- [ ] When a substance burns it reacts with oxygen.
- [ ] The alkanes and alcohols can be used as fuels.
- [ ] The relationship $E_h = cm\Delta T$ is used to calculate the quantity of heat transferred when a substance changes temperature.

  c = specific heat capacity (4·18 J °C^{-1} kg^{-1} for water)

  m = mass of substance which absorbed heat

  ΔT = temperature change

- [ ] Balanced chemical equations can be used to calculate the mass of products from a known mass of reactants.
- [ ] The following apparatus is used to find the heat released when an alcohol (methanol) burns:



- [ ] The following measurements are needed to allow the quantity of heat to be calculated:

  i) Mass/Volume of water

  ii) Mass of burner and alcohol at the start

  iii) Mass of burner and alcohol at the end

  iv) Initial temperature of the water

  v) Highest temperature of the water.