

# **Chemistry in society**

## **Homework exercise**

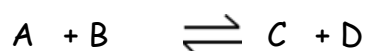


**Equilibrium, Hess Law, Enthalpy**

## Equilibrium

## Exercise 1

1) A reaction can be described as



- Write an equation to show the forwards reaction
- Write an equation to show the reverse reaction

2) What happens to:

- the concentration of reactants and products
- the rate of the forwards and reverse reactions

when a reaction reaches equilibrium?

3) What does the term 'dynamic equilibrium' mean?

4) Define Le Chatelier's principle

5) What will happen to a reaction at equilibrium when:

- The pressure is increased
- The temperature is increased
- The concentration of a reactant is increased
- A substance is added which reacts with and removes a reactant

6) Use Le Chatelier's principle to explain each of your answers to question 5.

7) What effect will addition of a catalyst have on:

- the rate of the forward reaction
- the rate of the reverse reaction
- the time taken to reach equilibrium
- the position of the equilibrium

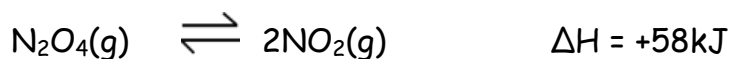
## Equilibrium

## Exercise 2

1) Chemical reactions are in a state of dynamic equilibrium only when:

- A The rate of the forward reaction equals that of the backward reaction.
- B The concentration of reactants and products are equal.
- C The activation energies of the forward and backward reactions are equal.
- D The reaction involves zero enthalpy change.

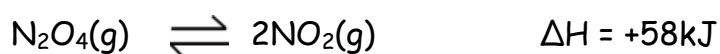
2) Increasing the pressure on the equilibrium shown below:



Will cause the position of the equilibrium to

- A move to the product side
- B move to the reactant side
- C remain unchanged
- D increase

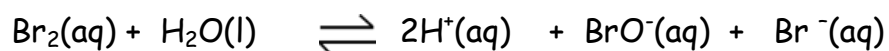
3) Decreasing the temperature in the reaction shown below



Will cause the position of the equilibrium to

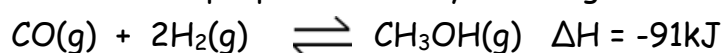
- A move to the product side
- B move to the reactant side
- C remain unchanged
- D increase

Questions 4 and 5 refer to the following equilibrium which exists in bromine water.



- 4) Addition of which of the following substances would move the equilibrium position to the right?
- A potassium nitrate
  - B sodium bromide
  - C sulphuric acid
  - D sodium hydroxide
- 5) Addition of which of the following substances would increase the pH of the equilibrium mixture?
- A potassium nitrate
  - B sodium bromide
  - C bromine
  - D sodium chloride

6) Methanol can be prepared from synthesis gas as follows:



The formation of methanol is favoured by:

- A high pressure and low temperature
- B high pressure and high temperature
- C low pressure and low temperature
- D low pressure and high temperature

7) In the Haber process nitrogen and hydrogen are converted into ammonia in an exothermic equilibrium reaction. The operating conditions are 250 atmospheres pressure and a temperature of about 500°C in the process.

a) Write a balanced equation for the reaction.

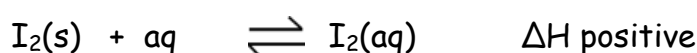
b) The highest percentage yield of ammonia would be obtained at a low operating temperature. Explain, therefore, the use of a temperature of about 500°C in the process.

c) The reaction is not allowed to reach equilibrium.

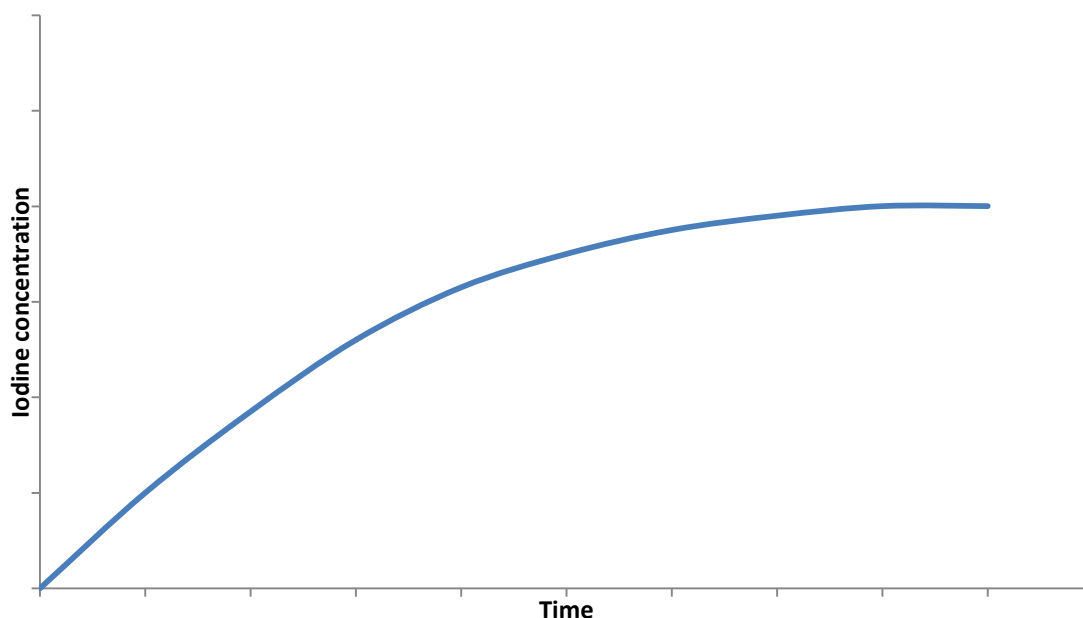
i) State how this is done.

ii) Explain why this is done.

8) Iodine dissolves only slightly in water, the process being endothermic. With excess iodine present, the following equilibrium is set up.

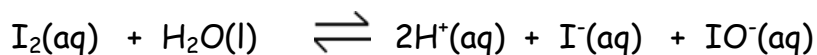


The concentration of dissolved iodine was measured over a period of time. The graph below was obtained as the iodine dissolved.



a) Copy the graph and add a curve to show how the iodine concentration would change with time if the measurements were repeated at a higher temperature.

b) The dissolved iodine reacts with water as follows:

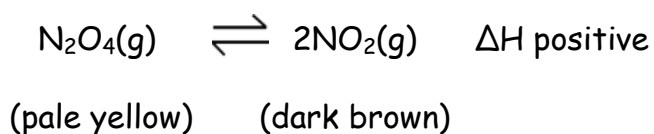


i) Copy and complete the table to show the effect on the equilibrium of adding each of the solids.

Solid	Effect on equilibrium position
Potassium iodide	
Potassium sulphate	

ii) Why does the position of the equilibrium move to the right when solid potassium hydroxide is added?

9) Consider the following equilibrium:



What would be **seen** if the equilibrium mixture was:

a) placed in a freezing mixture

b) compressed?

## Equilibrium

## Exercise 3



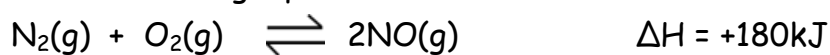
Which two conditions favour the decomposition of  $\text{NO}_2$ ?

- A low temperature, high pressure
- B high temperature, low pressure
- C low temperature, low pressure
- D high temperature, high pressure

2) Which of the following is likely to apply to the use of a catalyst in a chemical reaction?

	Rate of forward reaction	Rate of reverse reaction	Position of equilibrium
A	Increased	Unchanged	Moves right
B	Increased	Increased	Unchanged
C	Increased	Decreased	Moves right
D	unchanged	unchanged	unchanged

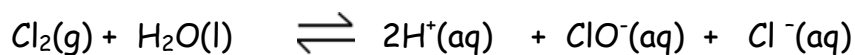
3) Consider the following equilibrium:



How would the equilibrium concentration of nitrogen oxide be affected by:

- a) increasing the temperature
- b) decreasing the pressure
- c) decreasing the concentration of oxygen

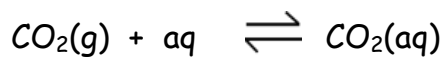
4) When chlorine is dissolved in water, the following equilibrium is set up.



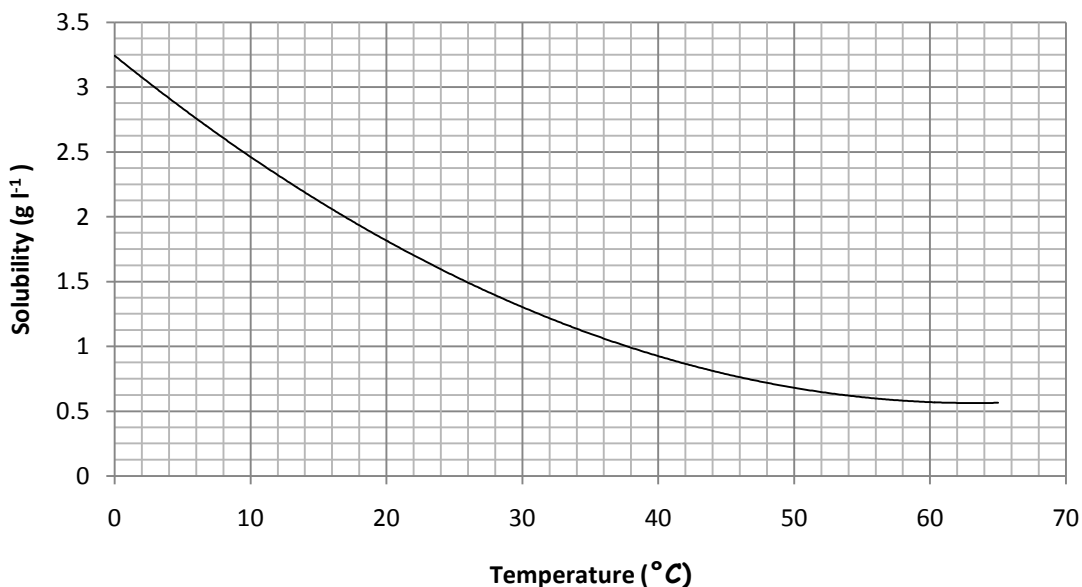
The efficiency of a chlorine bleach depends on a high concentration of  $\text{ClO}^-$  ions. Various substances can be added to achieve this, e.g sodium carbonate and silver nitrate.

- Explain why each of these compounds should increase the concentration of  $\text{ClO}^-$  ions.
- Why is silver nitrate unlikely to be used in practice.
- Explain what effect adding potassium hydroxide solution would have on the position of the equilibrium.

5) Soda water is made by dissolving carbon dioxide in water, under pressure.



- When the stopper is taken off a bottle of soda water, the carbon dioxide gas escapes. Explain why the drink eventually goes **completely** flat.
- This graph shows the solubility of carbon dioxide in water at different temperatures.

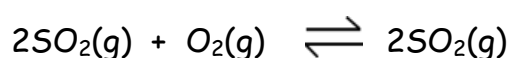




What does the graph indicate about the enthalpy of solution of carbon dioxide in water?

c) When all of the carbon dioxide is removed from one litre of soda water at  $0^{\circ}\text{C}$ , the gas is found to occupy 1.7 litres. Use the information in the graph to calculate the molar volume of carbon dioxide at this temperature.

6) In the contact process, sulphur trioxide is formed from sulphur dioxide and oxygen in a reversible reaction. The equation for the reaction is:



The forward reaction is exothermic.

a) One litre of sulphur dioxide and one litre of oxygen were mixed under certain conditions and allowed to reach equilibrium. Analysis of the equilibrium mixture showed that 60% conversion of the sulphur dioxide had taken place.

Calculate the volume of each gas present in the equilibrium mixture.

b) What effect, if any, will there be on the equilibrium position if:

i) the temperature is increased

ii) a catalyst is used

iii) the pressure is increased?

## Enthalpy revision

## Exercise 4

1) What name is given to the device which measures the energy given out by a fuel?

2) Copy the passage and delete the incorrect phrases.

The burning of a fuel is an endothermic / exothermic reaction in which energy is given out / taken in. This means the products have more / less energy than the reactants.

3) Using the equation  $E_h = cm\Delta T$  calculate the energy given out in the following examples. Show working.

- a) Methane burns and raises the temperature of  $200\text{cm}^3$  of water from  $20^\circ\text{C}$  to  $30.5^\circ\text{C}$ .
- b) Propanol is burned causing the temperature of  $500\text{cm}^3$  of water to increase by  $23^\circ\text{C}$ .
- c) A fuel burns, increasing the temperature of  $150\text{cm}^3$  of water by  $12^\circ\text{C}$ .
- d) The temperature of  $50\text{cm}^3$  of water increases from  $25^\circ\text{C}$  to  $29^\circ\text{C}$  when propane burns.

4) When butanol burns the temperature of  $250\text{cm}^3$  of water increases by  $16^\circ\text{C}$ . The energy released is:

- A. 16.7 kJ
- B. 167 kJ
- C. 16720 kJ
- D. 1.67 kJ

5) A can containing 0.1kg of water at  $21^\circ\text{C}$  is heated to  $29^\circ\text{C}$  when a burner containing an alcohol is lit underneath it. Calculate the energy given out.

6) The burning of methane is used to raise the temperature of 0.25L of water from  $18.5^\circ\text{C}$  to  $28.5^\circ\text{C}$ . Calculate the energy given out.

7) Propane is burned to heat  $250\text{cm}^3$  of water from  $22.5^\circ\text{C}$  to  $31^\circ\text{C}$ . Calculate the energy given out.

## Calculating Enthalpy of combustion

## Exercise 5

- 1) Why is it important to predict the enthalpy change of an industrial reaction?
- 2) When 0.58g of butane ( $C_4H_{10}$ ) was burned, the heat produced raised the temperature of  $200\text{cm}^3$  of water from  $20^\circ\text{C}$  to  $54.5^\circ\text{C}$ . Calculate the enthalpy of combustion of butane.
- 3) 0.02 moles of a hydrocarbon is burned completely in air and the heat produced is used to heat 0.1kg of water from  $20.5^\circ\text{C}$  to  $29.5^\circ\text{C}$ . Calculate the enthalpy of combustion of the fuel.
- 4) A can containing 0.1kg of water at  $21^\circ\text{C}$  is heated to  $29^\circ\text{C}$  when a burner containing alcohol is lit underneath it. If 0.02 moles of the alcohol is burned in the process, calculate its enthalpy of combustion.
- 5) 0.32g of methanol  $CH_3OH$  is burned in a spirit burner which is used to heat up 0.2kg of water from  $19.5^\circ\text{C}$  to  $27.5^\circ\text{C}$ . Calculate the enthalpy of combustion of methanol.
- 6) The burning of 0.2g of methane,  $CH_4$ , is used to raise the temperature of 0.25kg of water from  $18.5^\circ\text{C}$  to  $28.5^\circ\text{C}$ . Calculate the enthalpy of combustion of methane.
- 7) A burner containing ethanol,  $C_2H_5OH$ , is used to heat up 0.4kg of water from  $21^\circ\text{C}$  to  $37^\circ\text{C}$ . In the process, 0.92g of ethanol is burned. Calculate the enthalpy of combustion of ethanol.
- 8) 0.22g of propane,  $C_3H_8$ , is burned to heat 0.25kg of water by  $10^\circ\text{C}$ . Calculate the enthalpy of combustion of propane.
- 9) A gas burner containing butane,  $C_4H_{10}$ , is used to heat 0.15kg of water from  $22.5^\circ\text{C}$  to  $31^\circ\text{C}$ . 0.116g of butane is burned in the process. Calculate the enthalpy of combustion of butane.

## Re-arranging $E_h = cm\Delta T$

## Exercise 6

- 1) The enthalpy of combustion of ethanol,  $C_2H_5OH$ , is  $-1367\text{kJ mol}^{-1}$ . If a spirit burner containing ethanol was used to heat a can of water, what mass of ethanol would raise the temperature of  $300\text{cm}^3$  of water by  $10^\circ\text{C}$ ?
- 2) The enthalpy of combustion of propanol is  $-2020\text{kJ mol}^{-1}$ . A burner containing propanol,  $C_3H_7OH$ , is used to heat up  $200\text{cm}^3$  of water. What mass of propanol would require to be burned to produce a temperature rise of  $13.5^\circ\text{C}$ ?
- 3) A bunsen burner uses methane,  $CH_4$ , which has an enthalpy of combustion of  $-891\text{kJ mol}^{-1}$ . If  $0.4\text{g}$  of methane were completely burned to heat a can containing  $500\text{cm}^3$  of water, what would be the maximum temperature rise which would be produced?
- 4) The enthalpy of combustion of methanol was calculated experimentally as  $-669\text{kJ mol}^{-1}$ .  $0.02$  moles of methanol are used to heat  $300\text{cm}^3$  of water.
  - a) Calculate the temperature rise of the water.
  - b) Explain why the experimentally derived enthalpy of combustion is significantly lower than the value quoted in the databook.
- 5) The enthalpy of combustion of ethanol,  $C_2H_5OH$ , is  $-1367\text{kJ mol}^{-1}$ . If a spirit burner containing ethanol was used to heat a can of water, what temperature rise would occur when  $0.5\text{g}$  of ethanol are used to heat  $100\text{cm}^3$  of water.
- 6) The enthalpy of combustion of methanol is  $-727\text{kJ mol}^{-1}$ . A burner containing methanol,  $CH_3OH$ , is used to heat up  $400\text{cm}^3$  of water. What temperature rise would be produced in the water if  $0.64\text{g}$  of methanol were completely burned?
- 7) An experiment was carried out using an ethanol burner.
  - a) Write the equation for the complete combustion of ethanol,  $C_2H_5OH(l)$  and write down the enthalpy of combustion from your data book.
  - b) If the apparatus used is  $50\%$  efficient, calculate the mass of ethanol burned when  $80\text{cm}^3$  of water rises in temperature from  $20.5^\circ\text{C}$  to  $31.0^\circ\text{C}$ .

## Enthalpy past paper questions

## Exercise 7

1) The boiling point of pentane is  $36^{\circ}\text{C}$ . Which equation illustrates the enthalpy of combustion of pentane?

- A  $\text{C}_5\text{H}_{12}(\text{l}) + 8\text{O}_2(\text{g}) \rightarrow 5\text{CO}_2(\text{g}) + 6\text{H}_2\text{O}(\text{l})$
- B  $\text{C}_5\text{H}_{12}(\text{l}) + 5.5\text{O}_2(\text{g}) \rightarrow 5\text{CO}(\text{g}) + 6\text{H}_2\text{O}(\text{l})$
- C  $\text{C}_5\text{H}_{12}(\text{g}) + 8\text{O}_2(\text{g}) \rightarrow 5\text{CO}_2(\text{g}) + 6\text{H}_2\text{O}(\text{g})$
- D  $\text{C}_5\text{H}_{12}(\text{l}) + 5\text{O}_2(\text{g}) \rightarrow 5\text{CO}_2(\text{g}) + 6\text{H}_2(\text{g})$

2) When 3.6g of glucose,  $\text{C}_6\text{H}_{12}\text{O}_6$ , was burned, 56kJ of energy was released. From this data, what is the enthalpy of combustion of glucose in  $\text{kJ mol}^{-1}$ ?

- A -15.6
- B +15.6
- C -2800
- D +2800

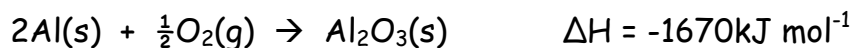
3) The enthalpy of combustion of benzene ( $\text{C}_6\text{H}_6$ ) is  $-3268\text{kJ mol}^{-1}$ . When 1.8g of benzene is completely burned the enthalpy change is:

- A -32.7kJ
- B -75.4kJ
- C -32.7kJ
- D -65.4kJ

4)  $5\text{N}_2\text{O}_4(\text{l}) + 4\text{CH}_3\text{NHNH}_2(\text{l}) \rightarrow 4\text{CO}_2(\text{g}) + 12\text{H}_2\text{O}(\text{l}) + 9\text{N}_2(\text{g}) \quad \Delta\text{H} = -5116\text{kJ}$   
The energy released when 2 moles of each reactant are mixed and ignited is:

- A 2046kJ
- B 2558kJ
- C 4093kJ
- D 5116kJ

5) Aluminium reacts with oxygen to form aluminium oxide.



What is the enthalpy of combustion of aluminium in  $\text{kJ mol}^{-1}$ ?

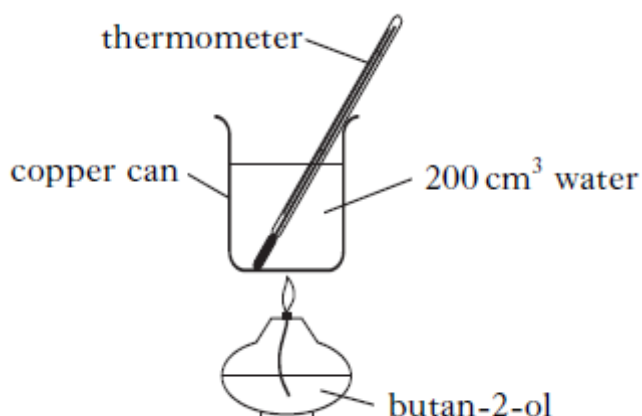
- A -835
- B -1113
- C -1670
- D +1670

6) The enthalpies of combustion of some alcohols are shown in the table below:

Name of alcohol	Enthalpy of combustion / $\text{kJ mol}^{-1}$
Methanol	-727
Ethanol	-1367
Propan-1-ol	-2020

a) Using this data predict the enthalpy of combustion of butan-1-ol in  $\text{kJ mol}^{-1}$ .

b) A value for the combustion of butan-2-ol,  $\text{C}_4\text{H}_9\text{OH}$ , can be determined experimentally using the apparatus shown.

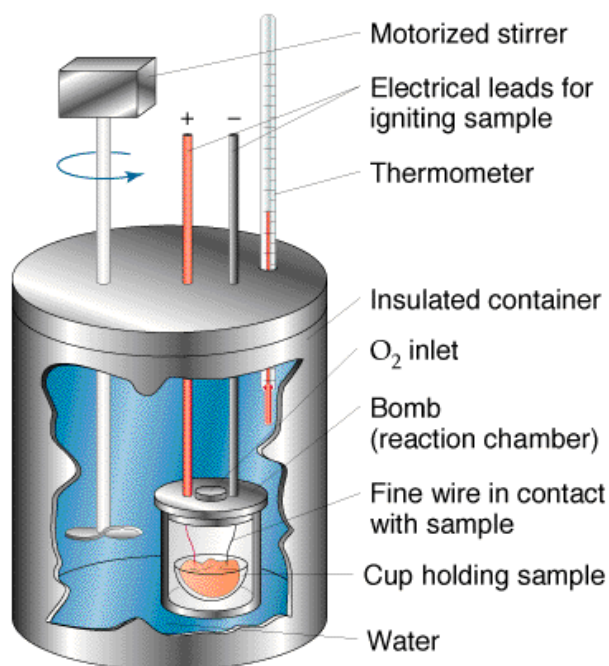


Mass of butan-2-ol burned = 1.0g

Temperature rise of water = 40°C

Use these results to calculate the enthalpy of combustion of butan-2-ol in  $\text{kJ mol}^{-1}$ .

7) A calorimeter like the one shown below can be used to measure the enthalpy of combustion of ethanol. The ethanol is ignited and burns completely in the oxygen gas. The heat energy released in the reaction is taken in by the water



a) Explain why the sample is stirred.

b) The value for the enthalpy of combustion of ethanol obtained by the calorimeter method is higher than the value obtained by the typical school method.

One reason for this is that more heat is lost to the surroundings in the school method. Give **one** other reason for the value being higher with the calorimeter method.

c) In one experiment the burning of 0.980g of ethanol resulted in the temperature of 400cm<sup>3</sup> of water rising from 14.2°C to 31.6°C.

Use this information to calculate the enthalpy of combustion of ethanol.

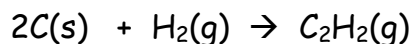
Show your working clearly.

## Hess Law - given equations

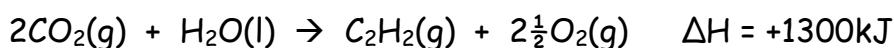
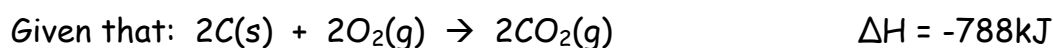
## Exercise 8

1) Define Hess Law

2) The enthalpy of formation of ethyne:

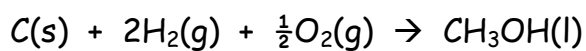


Can be calculated using the enthalpies of combustion of carbon, hydrogen and ethyne.

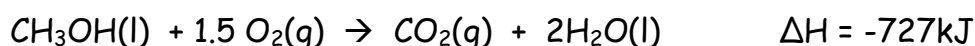


Calculate the enthalpy of formation of ethyne.

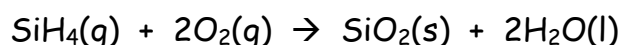
3) Methanol can be formed from hydrogen, carbon and oxygen as follows:



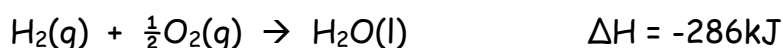
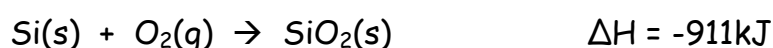
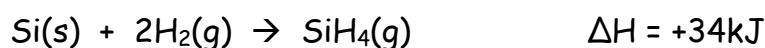
Use the enthalpies of combustion of carbon, hydrogen and methanol to calculate the enthalpy change for this reaction.



4) The simplest silicon hydride has the formula  $\text{SiH}_4$ . It is a gas at room temperature. The equation for the complete combustion of this compound is:

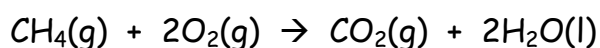


Calculate the enthalpy change for this reaction using the following data:

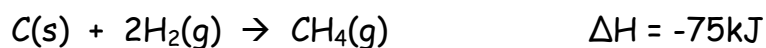
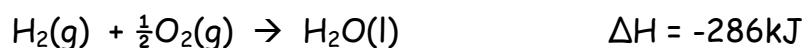




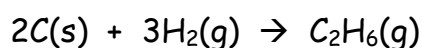
5) The equation for the combustion of methane, CH<sub>4</sub>, is given below:



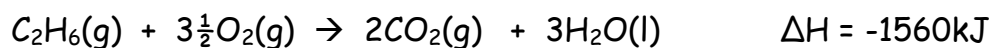
Calculate the enthalpy of combustion of methane using the data below:



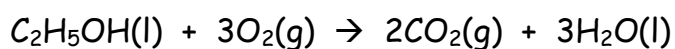
6) The enthalpy of formation of ethane, C<sub>2</sub>H<sub>6</sub>, is represented by the following equation:



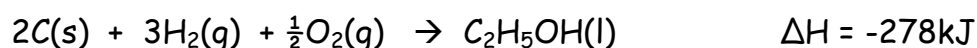
Calculate the enthalpy of combustion of ethane using the data below:



7) The equation for the combustion of ethanol, C<sub>2</sub>H<sub>5</sub>OH, is given below:



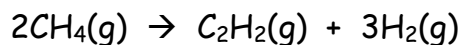
Calculate the enthalpy of combustion of methane using the data below:



## Hess Law- deriving equations

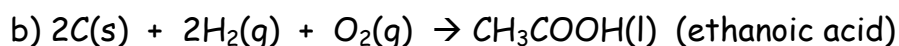
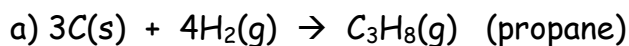
## Exercise 9

- 1) Methane can be converted into ethyne at very high temperatures (about 1500°C). The equation for the reaction is:

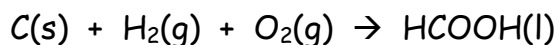


Use the enthalpies of combustion from the SQA data book to calculate the enthalpy change for this reaction.

- 2) Use appropriate enthalpies of combustion from the SQA data book to calculate the enthalpy changes for the following reactions.

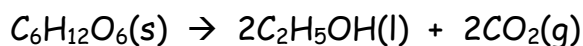


- 3) The formation of methanoic acid, HCOOH, is represented by the following equation:



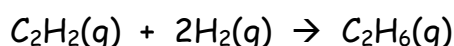
Calculate  $\Delta H$  for the above reaction using the enthalpies of combustion of carbon, hydrogen and methanoic acid.

- 4) The fermentation of glucose,  $\text{C}_6\text{H}_{12}\text{O}_6$ , to ethanol and carbon dioxide can be represented by the equation below:



Calculate the  $\Delta H$  for this reaction using the enthalpies of combustion of ethanol and glucose. (The enthalpy of combustion of glucose is  $-2813\text{kJ mol}^{-1}$ ).

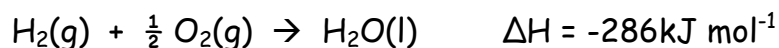
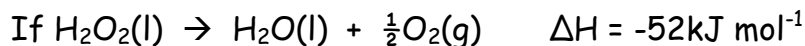
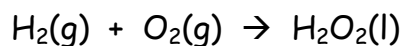
- 5) Use the enthalpies of combustion of ethyne,  $\text{C}_2\text{H}_2$ , ethane,  $\text{C}_2\text{H}_6$  and hydrogen to calculate the  $\Delta H$  for the complete hydrogenation of ethyne given by the equation below:



## Hess Law past paper questions

## Exercise 10

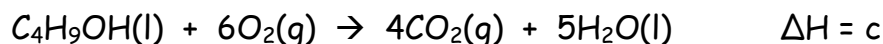
1) The formation of hydrogen peroxide can be shown as:



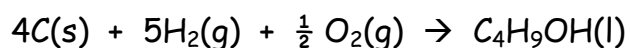
What is the enthalpy of formation of hydrogen peroxide ( $\text{H}_2\text{O}_2$ )?

- A  $-234\text{kJ mol}^{-1}$
- B  $+234\text{kJ mol}^{-1}$
- C  $-338\text{kJ mol}^{-1}$
- D  $+338\text{kJ mol}^{-1}$

2) The enthalpies of combustion of  $\text{C}(\text{s})$ ,  $\text{H}_2(\text{g})$  and  $\text{C}_4\text{H}_9\text{OH}(\text{l})$  (in  $\text{kJ mol}^{-1}$ ) are as follows:



The enthalpy of formation of butanol is:



Which of these equations could be used to calculate the enthalpy of formation of butanol?

- A  $4a + 5b - c$
- B  $2a + 10b - c$
- C  $c - 4a - 5b$
- D  $2a + 5b + c$

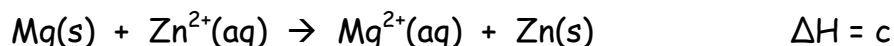
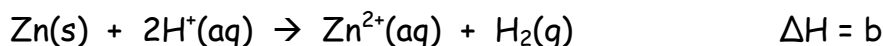
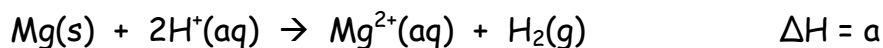
3) Consider the reaction:



What is the  $\Delta H$  for the reaction  $A + 3B \rightarrow 2C$ ?

- A -96kJ
- B -48kJ
- C +96kJ
- D +48kJ

4) Given these equations:

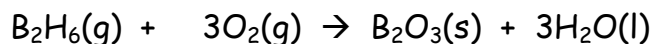


Then according to Hess's law:

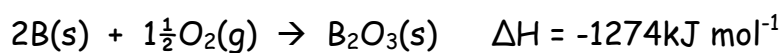
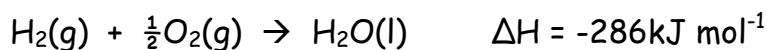
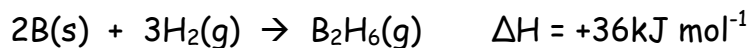
- A  $c = a + b$
- B  $c = a - b$
- C  $c = b - a$
- D  $c = -b - a$

5) Diborane is used as rocket fuel.

The equation for the combustion of diborane is shown below:



a) Calculate the enthalpy of combustion of the gas diborane  $\text{B}_2\text{H}_6$  using the following data:

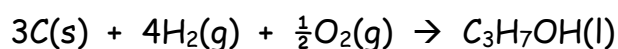


b) Diborane can be used to manufacture pentaborane (B<sub>5</sub>H<sub>9</sub>).

Pentaborane was also considered for use as a rocket fuel because its enthalpy of combustion is -9037kJ mol<sup>-1</sup>.

Calculate the energy released, in kJ, when 1 kilogram of pentaborane is completely burned.

6) The equation for the enthalpy of formation of propan-1-ol is:



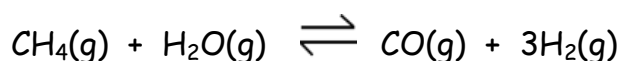
Use information on enthalpies of combustion from the data book to calculate the enthalpy of formation of propan-1-ol.

Show your working clearly.

7) Mobile phones are being developed that can be powered by methanol.

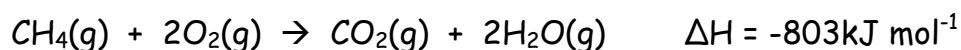
Methanol can be made in a two stage process.

In the first stage, methane is reacted with steam to produce a mixture of hydrogen and carbon monoxide.



a) Give the name for the mixture of carbon monoxide and hydrogen which is produced.

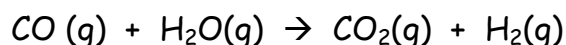
b) Use the data below to calculate the enthalpy change, in kJ mol<sup>-1</sup>, for the forward reaction.



## Bond enthalpy

## Exercise 11

- 1) Use the bond enthalpies quoted in the databook to answer the following questions:
  - a) Which halogen has the strongest bond?
  - b) Which hydrogen-halogen bond is the easiest to break?
  - c) Explain why nitrogen has a higher bond enthalpy than oxygen
- 2) Calculate the energy required (in kJ) to break 4g of hydrogen gas into atoms.
- 3) Explain why a C-H bond enthalpy is called a mean bond enthalpy whilst a H-H bond enthalpy is called a molar bond enthalpy.
- 4) Use bond enthalpies to calculate the enthalpy changes for the following reactions:
  - a)  $\text{H}_2(\text{g}) + \text{Cl}_2(\text{g}) \rightarrow 2\text{HCl}(\text{g})$
  - b)  $2\text{H}_2(\text{g}) + \text{O}_2(\text{g}) \rightarrow 2\text{H}_2\text{O}(\text{g})$
  - c)  $\text{H}_2(\text{g}) + \text{F}_2(\text{g}) \rightarrow 2\text{HF}(\text{g})$
  - d)  $\text{C}(\text{g}) + 2\text{H}_2(\text{g}) \rightarrow \text{CH}_4(\text{g})$
  - e)  $\text{HCl}(\text{g}) + \frac{1}{2} \text{F}_2(\text{g}) \rightarrow \text{HF}(\text{g}) + \frac{1}{2} \text{Cl}_2(\text{g})$
- 5) Use the bond enthalpies quoted below to calculate the enthalpy change for this reaction:



Bond	Enthalpy ( $\text{kJ mol}^{-1}$ )
C-O in carbon monoxide	+358
C=O in carbon dioxide	+798
O-H	+458
H-H	+432