DEPARTMENT OF CHEMISTRY

CfE HIGHER CHEMISTRY

UNIT 3
CHEMISTRY IN SOCIETY
HOMEWORK BOOKLET

Name

Designing an Industrial Process

1. Aluminium is extracted from its purified oxide by molten electrolysis. Suggest two advantages and two disadvantages of siting aluminium smelters in the Scottish Highlands.

2. Write down 5 factors which will affect the design of a chemical process.

3. A reaction in a chemical plant is exothermic.
   (a) Explain what is meant by an exothermic reaction.
   (b) How does the exothermic reaction help the chemical plant make a profit?

4. By-products are usually created in industrial chemical processes.
   (a) Explain what is meant by a by-product.
   (b) How can by-products be
      (i) profit making?
      (ii) profit losing?

5. As well as transportation, what other reasons could there be for siting chemical works close to rivers?

6. What are the four stages in the manufacture of a new product? Write a sentence or two to explain each stage.

7. Imagine you were researching a method for converting benzene to a long chain alkylbenzene for detergent manufacture. What amounts of reagents would you use?
   A milligrams
   B grams
   C kilograms
   D metric tonnes (1000 kg)

8. In the bulk manufacturing process for converting benzene to alkylbenzene for detergents, what amounts of reagents would be used?
   A milligrams
   B grams
   C kilograms
   D metric tonnes (1000 kg)

9. Give three ways that the operators of chemical plants can minimize the effect of the processes on the environment.

10. The Haber process is used to make ammonia. For this process list
   (a) the feedstocks
   (b) the raw materials

Calculations from Equations

number of moles = $\frac{mass}{GFM}$	*concentration* = $\frac{\text{number of moles}}{\text{volume}}$

1. What is the mass of
   a) 1 mole of H_2O
   b) 5 moles of CO_2
   c) 20 moles of NH_3
   d) 0.1 moles of C_2H_5OH
   e) 0.05 moles of C_2H_4?

2. How many moles are in
   a) 1.8g of H_2O
   b) 8.8g of CO_2
   c) 1.755kg of NaCl
   d) 40kg of MgO
   e) 0.12g of NaOH

3. What is the concentration of a solution containing:
   a) 5 moles of NaCl dissolved in 5 l of water
   b) 0.3 moles of NaCl dissolved in 0.5 l of water
   c) 2 moles of NaCl dissolved in 250 ml of water
   d) 175.5g of NaCl dissolved in 500 ml of water
   e) 11.7g of NaCl dissolved in 10 l of water

4. Calculate the number of moles of solute required to prepare $250cm^3$ of a 0.100 mol l^{-1} solution of oxalic acid.

5. What mass of copper(II) sulphate crystals ($CuSO_4.5H_2O$) would be contained in $100cm^3$ of a 2.50 mol l^{-1} solution ?

6. How many grams of magnesium oxide would be produced by reacting completely 4.0 g of magnesium with oxygen?

   $2Mg + O_2 \rightarrow 2MgO$

7. Oxygen can be converted into ozone (O_3) by passing an elecrical discharge through it. Calculate the number of ozone molecules that would be formed if 16g of oxygen were completely converted into ozone.
   $3O_2 \rightarrow 2O_3$

8. Ammonia reduces copper(II) oxide to copper. The other products of the reaction are water and nitrogen.

$2NH_3 + 3CuO \rightarrow 3Cu + H_2O + N_2$

Calculate the mass of copper produced and the mass of ammonia consumed when 56.4g of copper(II) oxide are reduced in this way.

9. What mass of aluminium will be needed to react with 10 g of CuO, and what mass of Al_2O_3 will be produced?

$3CuO + 2Al \rightarrow Al_2O_3 + 3Cu$

10. In a reaction magnesium carbonate powder is used to neutralise 250 cm^3 of 2 mol l^{-1} dilute hydrochloric acid. Calculate the mass of magnesium carbonate required to neutralise the dilute hydrochloric acid

$MgCO_3 + 2HCl \rightarrow MgCl_2 + H_2O + CO_2$

11. In a reaction sodium carbonate powder is used to neutralise 200 cm^3 of 2 mol l^{-1} dilute sulphuric acid. Calculate the mass of sodium carbonate required to neutralise the dilute sulphuric acid.

$Na_2CO_3 + H_2SO_4 \rightarrow Na_2SO_4 + H_2O + CO_2$

12. 20 cm^3 of a solution of NaOH is exactly neutralised by 25 cm^3 of a solution of HCl of concentration 0.5 mol l^{-1}.

$HCl + NaOH \rightarrow NaCl + H_2O$

Calculate the concentration of the NaOH solution in mol l^{-1}.

13. 100 cm^3 of a solution of KOH is exactly neutralised by 150 cm^3 of a solution of H_2SO_4 of concentration 0.25 mol l^{-1}.

$H_2SO_4 + 2KOH \rightarrow K_2SO_4 + 2H_2O$

Calculate the concentration of the KOH solution in mol l^{-1}.

14. 50 cm^3 of a solution of HCl is exactly neutralised by 20 cm^3 of a solution of $Ca(OH)_2$ of concentration 2.0 mol l^{-1}.

$2HCl + Ca(OH)_2 \rightarrow CaCl_2 + 2H_2O$

Calculate the concentration of the HCl solution in mol l^{-1}.

15. 2.5 l of a solution of NaOH is exactly neutralised by 1.5 l of a solution of HCl of concentration 1.0 mol l^{-1}.

$HCl + NaOH \rightarrow NaCl + H_2O$

Calculate the concentration of the NaOH solution in mol l^{-1}.

The molar volume of any gas is 24 litres at s.t.p.

16. What volume would the following amounts of gas occupy?
a) 2 moles of helium
b) 0.1 moles of oxygen
c) 5.5 moles of nitrogen
d) 2.4 g of ozone
e) 0.88 g of carbon dioxide
f) 32 g of sulphur trioxide

17. What volume (in l) of carbon dioxide would be produced by completely reacting 60 g of carbon with oxygen?

$C + O_2 \rightarrow CO_2$

18. What volume (in l) of hydrogen would be produced by completely reacting 60 cm^3 of hydrochloric acid of concentration 1.2 mol l^{-1} with zinc?

$Zn + 2HCl \rightarrow ZnCl_2 + H_2$

19. What volume (in l) of carbon dioxide would be produced by completely reacting 10g of calcium carbonate with hydrochloric acid?

$CaCO_3 + 2HCl \rightarrow CaCl_2 + H_2O + CO_2$

20. What volume (in l) of hydrogen would be produced by completely reacting 60 cm^3 of hydrochloric acid of concentration 1.2 mol l^{-1} with zinc?

$Zn + 2HCl \rightarrow ZnCl_2 + H_2$

21. In the reaction of lithium with water, what mass of lithium (in grams) would be required to produce 600 cm^3 of hydrogen?

$2Li + 2H_2O \rightarrow 2LiOH + H_2$

22. Calculate the volume of oxygen that would be required to react completely with 1.0 *l* of methane.

$CH_4 + 2O_2 \rightarrow CO_2 + 2H_2O$

23. Calculate the volume of oxygen that would be required to react completely with 5.0 *l* of ethane.

$C_2H_4 + 3O_2 \rightarrow 2CO_2 + 2H_2O$

24. Iron(II) sulphide reacts with hydrochloric acid as follows:

$FeS(s) + 2HCl(aq) \rightarrow FeCl_2(aq) + H_2S(g)$

If 4.4g of iron(II) sulphide was added to $160cm^3$ of 0.5 mol l^{-1} hydrochloric acid, show by calculation which substance is in excess.

25. A student added 0.20g of silver nitrate, $AgNO_3$, to 25 cm^3 of water. This solution was then added to $20cm^3$ of 0.0010 mol l^{-1} hydrochloric acid. The equation for the reaction is:

$AgNO_3(aq) + HCl(aq) \rightarrow AgCl(s) + HNO_3(aq)$

Show by calculation which reactant is in excess.

26. Calcite is a very pure form of calcium carbonate which reacts with nitric acid as follows:

$CaCO_3(s) + 2HNO_3(aq) \rightarrow Ca(NO_3)_2(aq) + H_2O(l) + CO_2(g)$

A 2.14g piece of calcite was added to $50.0cm^3$ of 0.200 mol l^{-1} nitric acid in a beaker. Calculate the mass of calcite, in grams, left unreacted.

27. Copper(II) oxide reacts with sulphuric acid as follows:

$CuO(s) + H_2SO_4(aq) \rightarrow CuSO_4(aq) + H_2O(l)$

1.6 g of copper(II) oxide is added to a beaker containing $50cm^3$ of 0.25 mol l^{-1} sulphuric acid. Calculate the mass of copper(II) oxide remaining after the reaction was complete.

28. Lead reacts with hydrochloric acid as follows:

$Pb(s) + 2HCl(aq) \rightarrow PbCl_2(aq) + H_2(g)$

If 6.22g of lead was added to 50cm^3 of 1 mol l^{-1} hydrochloric acid, calculate the mass of lea left unreacted.

29. A strip of zinc metal weighing 2.00 g is placed in an aqueous solution containing 10.00 g of silver nitrate. The reaction that occurs is

$Zn(s) + 2AgNO_3(aq) \rightarrow 2Ag(s) + Zn(NO_3)_2(aq)$

(a) Determine which reactant is in excess.
(b) Calculate how many grams of silver will be formed.

30. A piece of lithium with a mass of 1.50 g is placed in an aqueous solution containing 6.00 g of copper (II) sulphate. The reaction that occurs is:

$2Li(s) + CuSO_4(aq) \rightarrow Cu + Li_2SO_4\ (aq)$
(a) Determine which reactant is in excess.
(b) Calculate how many grams of copper will be formed.

Percentage Yield and Atom Economy

1. 20 g of lithium hydroxide was reacted with potassium chloride:

   $LiOH + KCl \rightarrow LiCl + KOH$

   (a) What is the theoretical yield of lithium chloride?
   (b) If 6 g of lithium chloride was actually produced, what is the percentage yield?

2. The equation below shows the combustion of propanol:

   $C_3H_8 + 5\ O_2 \rightarrow 3\ CO_2 + 4\ H_2O$

   a) If you start with 5 grams of C_3H_8, what is the theoretical yield of water?
   b) If the percentage yield was 75%, how many grams of water will actually be made?

3. In the reaction below, the theoretical yield was 10.7 g but the actual yield was 4.5 g. Calculate the percentage yield.

   $Be + 2\ HCl \rightarrow BeCl_2 + H_2$

4. What is the theoretical yield of sodium oxide if you start with 20 grams of calcium oxide?

   $2\ NaCl + CaO \rightarrow CaCl_2 + Na_2O$

5. In the reaction below:

   $FeBr_2 + 2\ KCl \rightarrow FeCl_2 + 2\ KBr$

   a) What is the theoretical yield of iron (II) chloride if you start with 340 g of iron (II) bromide?
   b) What is my percentage yield of iron (II) chloride if my actual yield is 40 g?

6. In the reaction below:

   $TiS + H_2O \rightarrow H_2S + TiO$

   What is the percentage yield of titanium (II) oxide if you start with 20 g of titanium (II) sulfide and the actual yield of titanium (II) oxide is 22 g?

7. In the reaction below:

$U + 3\ Br_2 \rightarrow UBr_6$

What is the actual yield of uranium hexabromide if you start with 100 g of uranium and get a percentage yield of 83% ?

8. In the reaction below:

$H_2SO_4 \rightarrow H_2O + SO_3$

If you start with 89 kg of sulfuric acid and produce 71 kg of water, what is the percentage yield?

9. If, in the reaction below 32 kg of C_2H_6 produces 44 kg of CO_2, what is the % yield?

$2C_2H_6 + 7O_2 \rightarrow 4CO_2 + 6H_2O$

10. If, in the reaction below, 80 g of Cl_2 produces 38 g of CCl_4 what is the % yield?

$CS_2 + 3Cl_2 \rightarrow CCl_4 + S_2Cl_2$

11. If, in the reaction below, 49 g of Fe_3O_4 produces a 78.25 % yield of Fe. How many grams are produced?

$Fe_3O_4 + 4H_2 \rightarrow 3Fe + 4H_2O$

12. If, in the reaction below, 40 tonnes of H_2O produces 6.7 tonnes of HF what is the % yield?

$CH_3COF + H_2O \rightarrow CH_3COOH + HF$

13. Calculate the atom economy for the production of lithium chloride assuming that all the reactants are converted into products.

$LiOH + KCl \rightarrow LiCl + KOH$

14. Calculate the atom economy for the production of titanium oxide assuming that all the reactants are converted into products.

$TiS + H_2O \rightarrow H_2S + TiO$

15. Calculate the atom economy for the production sulphur trioxide assuming that all the reactants are converted into products.

$H_2SO_4 \rightarrow H_2O + SO_3$

16. Which reaction below has the highest atom economy for producing water?

$2C_2H_6 + 7O_2 \rightarrow 4CO_2 + 6H_2O$
$C_3H_6 + 4\frac{1}{2}O_2 \rightarrow 3CO_2 + 3H_2O$

Equilibria

1. The reaction between SO_2 and O_2 may be described as

$$2SO_{2(g)} + O_{2(g)} \rightleftharpoons 2SO_{3(g)} \qquad \Delta H = -196 \text{ kJ mol}^{-1}$$

Select the two conditions that will favour a high yield of SO_3.

A Removal of SO_2
B Lower the pressure
C Lower the temperature
D Use a catalyst
E Addition of more O_2

2. A chemical reaction has reached dynamic equilibrium at a certain temperature. Which one of following statements is **incorrect**?

A The reaction has stopped completely
B The concentrations of the reactants remains constant
C Products are continuously being formed
D The rate of the forward reaction is equal to the rate of the reverse reaction

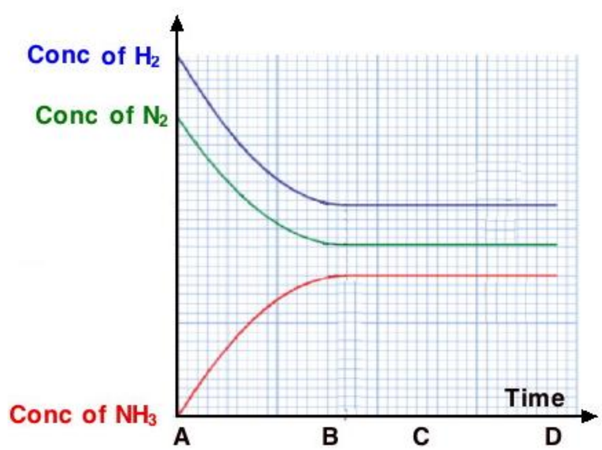
3. Three moles of ethanol and three moles of ethanoic acid were reacted together according to The equation

$$C_2H_5OH + CH_3COOH \rightleftharpoons CH_3COOC_2H_5 + H_2O$$

At equilibrium, there was 2 moles each of ethyl ethanoate and water formed. What is the equilibrium constant for this reaction?

A 4
B 2
C 0.25
D 0.44

4. The diagram shows the concentrations of hydrogen, iodine and hydrogen iodide for the reaction between hydrogen and iodine.
Which of the following statements is **incorrect**?



A the equilibrium lies predominantly to the left
B at point A on the time axis, the concentration of all three gases is zero
C The reaction between the gases reaches equilibrium at point B.
D Adding more hydrogen at point D will alter the shape of the graph.
E At point C, the system is in a state of dynamic equilibrium.

5. Consider the following equilibrium reaction

$$Cr_2O_7^{2-} + H_2O \rightleftharpoons 2CrO_4^{2-} + 2H^+$$

Orange Yellow

Which one of the following will cause a yellow colour to predominate?

A Addition of sodium hydroxide (NaOH)
B Addition of sodium chromate (Na_2CrO_4)
C Addition of hydrochloric acid (HCl)
D Removal of water

6. Which one of the following equilibrium reactions is **not** affected by a change in pressure?

A $N_{2(g)} + 3H_{2(g)} \rightleftharpoons 2NH_{3(g)}$
B $H_{2(g)} + I_{2(g)} \rightleftharpoons 2HI_{(g)}$
C $PCl_{3(g)} + Cl_{2(g)} \rightleftharpoons PCl_{5(g)}$
D $2NO_{2(g)} \rightleftharpoons N_2O_{4(g)}$

7. What does it mean to say that a chemical reaction has reached equilibrium?

8. The forward reaction of the equilibrium system below is endothermic. Dilute HCl is added and the colour changes to blue. What colour change occurs when the mixture is cooled?

$$Co(H_2O)_6^{2+} + 4Cl^- \rightleftharpoons CoCl_4^{2-} + 6H_2O$$

Pink Blue

9. The reaction of nitrogen dioxide (NO_2) forming dinitrogen tetroxide (N_2O_4) is exothermic in the forward direction.

$$2NO_2 \rightleftharpoons N_2O_4$$

Dark Brown Colourless

State **two** conditions will cause the equilibrium mixture to go dark brown?

10. Ammonia is formed in the Haber process according to the following balanced equation.

$N_2 + 3H_2 \rightleftharpoons 2NH_3$

The table shows the percentages of ammonia present at equilibrium under different conditions of temperature T and pressure P when hydrogen and nitrogen gases were mixed in a 3:1 molar ratio. Is this an endothermic or exothermic reaction? Give a reason for your answer.

P/atm \ *T*/K	573	673	773
10	15	4	1
100	51	25	10
200	63	36	18
1000	92	80	58

11. The following equilibrium involves two compounds of phosphorus.

$PCl_{3(g)} + 3NH_{3\,(g)} \rightleftharpoons P(NH_2)_{3(g)} + 3HCl_{(g)}$

(a) An increase in temperature moves the equilibrium to the left. What does this indicate about the enthalpy change for the forward reaction?

(b) What effect, if any, will an increase in pressure have on the equilibrium?

12. The balanced equation for a reaction at equilibrium is:

aA + bB $\rightleftharpoons$ cC + dD

(a) For this reaction, the equilibrium constant, K, can be defined as:

$$K = \frac{[C]^c\,[D]^d}{[A]^a\,[B]^b}$$

where [A] represents the concentration of A, etc and a represents the number of moles of A,etc.

(i) Write down the expression for the equilibrium constant for the following equilibrium.

$N_2(g) + 3H_2(g) \rightleftharpoons 2NH_3(g)$

(ii) What will happen to the position of the equilibrium if the reaction is carried out over a catalyst?

(b) In industry, the reaction of nitrogen with hydrogen to produce ammonia by the Haber Process does not attain equilibrium.
Give one feature of the operating conditions which leads to the Haber Process not reaching equilibrium

13. When a yellow solution of iron (III) chloride ($FeCl_3$)and a colourless solution of potassium thiocyanate (KCNS) were mixed in a test tube, a red colour appeared and the following equilibrium was established:

$$Fe^{3+}_{(aq)} + CNS^{-}_{(aq)} \rightleftharpoons Fe(CNS)^{2+}_{(aq)}$$

yellow red

Explain:

(a) the effect on the Fe^{3+} ion concentration of adding KCNS to the equilibrium mixture
(b) why changing the pressure has no effect on this reaction.

14. Consider the following equilibrium reaction at room temperature used to dissolve iodine (I_2) crystals in an aqueous solution of iodide ions (I^-).

$$I_{2(aq)} + I^{-}_{(aq)} \rightleftharpoons I_3^{-}{}_{(aq)}$$

State and explain the effect on the equilibrium concentration of triiodide ions of adding a substance that reacts with iodine, eg. starch.

Chemical Energy

Enthalpy

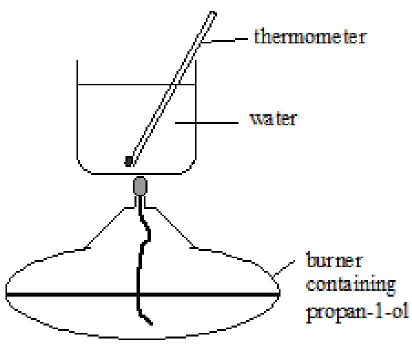
1. Calculate the quantity of heat required to raise the temperature of

(a) 1 kg of water by 15^0C
(b) 250 cm^3 of water by 7.8^0C
(c) 3 litres of water by 28^0C

2. A pupil burned 2.4g of sulphur in air to heat 150g of water. The temperature of the water increased from 15.3^0C to 36.0^0C.

Calculate the value for the enthalpy of combustion of sulphur using these experimental results.

3. A pupil found the enthalpy of combustion of propan-1-ol using the following apparatus.



(a) In addition to the initial and final temperatures of the water, what other measurements would the pupil have made.

(b) Describe a change that could be made to the experimental procedure in order to achieve more accurate results.

(c) The table shows the enthalpies of combustion of three alcohols.

Alcohol	Enthalpy of combustion/kJ mol^{-1}
methanol	-715
ethanol	-1371
propan-1-ol	-2010

Why is there a **regular** increase in enthalpies of combustion from methanol to ethanol to propan-1-ol?

4. When 3.6 g of butanal (relative formula mass =72) was burned, 134 kJ of energy was released.

From this result, what is the enthalpy of combustion in kJ mol^{-1}?

5. In an experiment the burning of 0.980g of ethanol resulted in the temperature of $400cm^3$ of water rising from 14.2°C to 31.6°C.

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

6. Calculate the enthalpy change for each of the following experiments.

(a) When 1 g of potassium carbonate dissolved in 10 cm^3 of water the temperature increased by 5.6^0C.

(b) When 1 g of sodium nitrate dissolved in 10 cm^3 of water the temperature fell by 5.6^0C.

7. From the results of question 6 calculate the **enthalpy of solution** for

a) potassium carbonate (6a)
b) sodium nitrate (6b)

8. The enthalpy change when 1 mole of sodium carbonate dissolves in water is 24.6 kJ mol^{-1}. Calculate the mass of sodium carbonate which would produce a temperature rise of 9.2^0C when added to $25cm^3$ of water.

9. 2g of sodium hydroxide, NaOH, is dissolved in 0.125 kg of water causing the temperature to rise from 19°C to 23°C.

Calculate the enthalpy of solution of sodium hydroxide.

10. 14.9g of potassium chloride, KCl, is dissolved in $200cm^3$ of water causing the temperature to fall from 19.5°C to 15.5°C.

Calculate the enthalpy of solution of potassium chloride.

11. A student dissolved 10.0g of ammonium chloride in $200cm^3$ of water and found that the temperature of the solution fell from 23.2°C to 19.8°C.

Calculate the enthalpy of solution of ammonium chloride.

12. A pupil added $50cm^3$ of NaOH(aq) to $50cm^3$ HCl(aq). Each solution had a concentration of 2.0 mol l^{-1}. The temperature rise was 13.5°C.

Calculate the enthalpy of neutralisation.

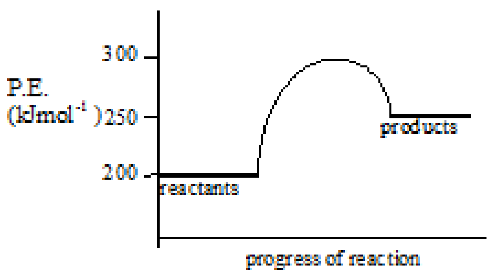
13. $40cm^3$ of 1 mol l^{-1} of nitric acid, HNO_3, and $40cm^3$ of 1 mol l^{-1} sodium hydroxide, NaOH, both at room temperature of 19°C were mixed and the temperature increased to 25.8°C.
Calculate the enthalpy of neutralisation.

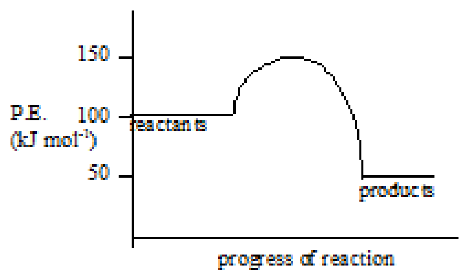
Chemical Energy

Enthalpy Diagrams

1. a) Copy the diagrams below and mark with an arrow:- i) the activation energy E_A.
ii) the enthalpy change Δ

b) State whether each reaction is endothermic or exothermic.

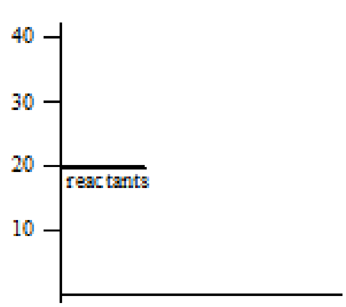


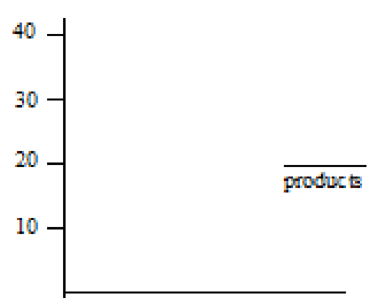


c) Calculate the value of ΔH and E_A for each reaction

2. Copy the axes below and sketch potential energy diagrams for the following reactions, labelling the axes.

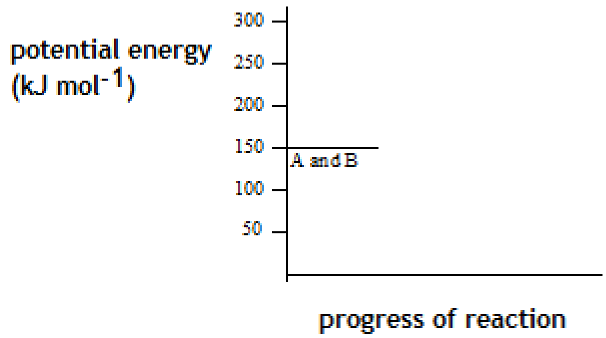
a) ΔH = -15 kJ mol^{-1} E_A = 20 kJ mol^{-1}
b) ΔH = +20 kJ mol^{-1} E_A = 35 kJ mol^{-1}



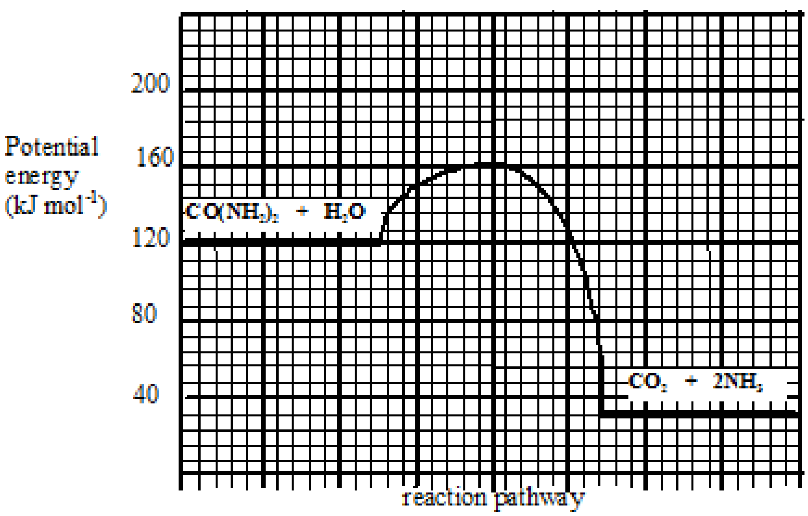


3. Two chemicals A and B react in solution to form C. The reaction has an activation energy of 150 kJ mol^{-1}. If hydrogen ions are used as a catalyst the activation energy is 50 kJ mol^{-1}. The enthalpy change for the reaction is -125 kJ mol^{-1}.

Present this information as a potential energy diagram using the template below.
Use a solid line for the uncatalysed reaction and a dotted line for the catalysed reaction.



4. The graph shows the potential energy diagram for a urease catalysis of urea.
(a) What is the enthalpy change for the reaction?
(b) Acid is a less effective catalyst than urease for this reaction.
Add a curve to the potential energy diagram to show the hydrolysis when acid is used as the catalyst.



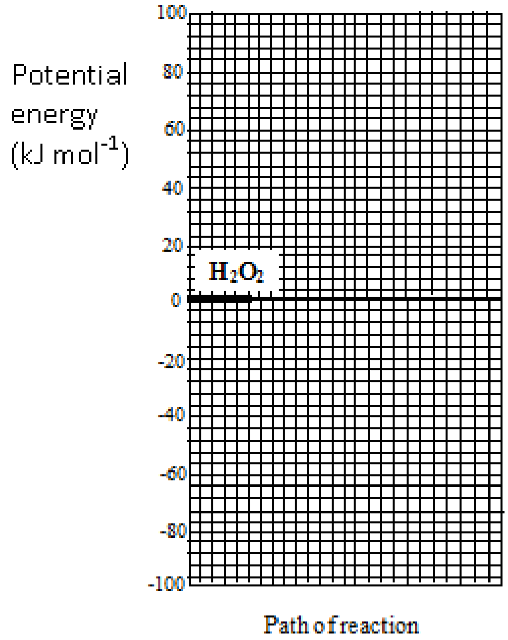
5. Hydrogen peroxide, H_2O_2, decomposes very slowly to produce water and oxygen.

(a) The activation energy (E_A) for the reaction is 75 kJ mol^{-1} and the enthalpy change (ΔH) is –26 kJ mol^{-1}.

Copy the diagram and use the information above to complete the potential energy diagram for the reaction using a solid line.

(b) When a catalyst is used the activation energy is reduced by 30 kJ mol^{-1}.

Add a dotted line to the diagram to show the path of reaction when a catalyst is used.



Chemical Energy

Hess's Law

1. What is the relationship between a, b, c and d? Answer in the form a = ...

$S_{(s)} + H_{2(g)} \rightarrow H_2S_{(g)}$	ΔH = a
$H_{2(g)} + \frac{1}{2} O_{2\,(g)} \rightarrow H_2O_{(l)}$	ΔH = b
$S_{(s)} + O_{2(g)} \rightarrow SO_{2(g)}$	ΔH = c
$H_2S_{(g)} + 1\frac{1}{2}\ O_{2(g)} \rightarrow H_2O_{(l)} + SO_{2(g)}$	ΔH = d

2. The enthalpy changes for the formation of one mole of aluminium oxide and one mole of iron(III) oxide are shown below.

$$2Al(s) + 1\tfrac{1}{2}O_2(g) \rightarrow Al_2O_3(s) \qquad \Delta H = -1676 \text{ kJ mol}^{-1}$$
$$2Fe(s) + 1\tfrac{1}{2}O_2(g) \rightarrow Fe_2O_3(s) \qquad \Delta H = -825 \text{ kJ mol}^{-1}$$

Use the above information to calculate the enthalpy change for the reaction:

$$2Al(s) + Fe_2O_3(s) \rightarrow Al_2O_3(s) + 2Fe(s)$$

3. The equation for the enthalpy of formation of propanone is:

$$3C(s) + 3H_2(g) + \tfrac{1}{2}O_2(g) \longrightarrow C_3H_6O(l)$$

Use the following information on enthalpies of combustion to calculate the enthalpy of formation of propanone.

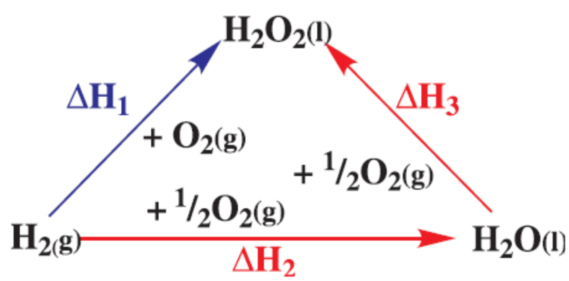
$$C(s) + O_2(g) \longrightarrow CO_2(g) \qquad \Delta H = -394\ kJmol^{-1}$$
$$H_2(g) + \tfrac{1}{2}O_2(g) \longrightarrow H_2O(l) \qquad \Delta H = -286\ kJmol^{-1}$$
$$C_3H_6O(l) + 4O_2(g) \longrightarrow 3CO_2(g) + 3H_2O(l) \qquad \Delta H = -1804\ kJmol^{-1}$$

4. The equation below represents the hydrogenation of ethene to ethane.

$$C_2H_4(g) + H_2(g) \longrightarrow C_2H_6(g)$$

Use the enthalpies of combustion of ethene, hydrogen and ethane from page 9 of the data booklet to calculate the enthalpy change for the above reaction.

5. Calculate a value for the enthalpy change involved in the formation of one mole of hydrogen peroxide from water (ΔH_3). The enthalpy change when hydrogen forms hydrogen peroxide is -188 kJ mol^{-1} and the enthalpy of combustion of hydrogen to form water is -286 kJ mol^{-1}.



6. Calculate a value for the enthalpy change involved in the decomposition of nitrogen dioxide to nitrogen monoxide given the following information.

Equation (a) $N_2(g) + O_2(g) \rightarrow 2NO(g)$ $\Delta H = +181$ kJ
equation (b) $N_2(g) + 2O_2(g) \rightarrow 2NO_2(g)$ $\Delta H = +68$ kJ

Chemical Energy

Bond Enthalpies

1. In the presence of bright light, hydrogen and bromine react. One step in the reaction is shown below.

$$H_2(g) + Br(g) \rightarrow HBr(g) + H(g)$$

The enthalpy change for this step can be represented as
A (H-H bond enthalpy) + (Br-Br bond enthalpy)
B (H-H bond enthalpy) − (Br-Br bond enthalpy)
C (H-H bond enthalpy) + (H-Br bond enthalpy)
D (H-H bond enthalpy) − (H-Br bond enthalpy).

2. Use the information in the table to calculate the enthalpy change for the following reaction:
$H_{2(g)} + Cl_{2(g)} \rightarrow 2HCl_{(g)}$

Bonds	ΔH to break bond (kJ mol^{-1})
H-H	432
Cl-Cl	243
H-Cl	428

3. Using the bond enthalpy values from your data booklet, calculate the enthalpy changes for the following reactions:

(a) $CH_{4(g)} + 2O_{2(g)} \rightarrow CO_{2(g)} + 2H_2O_{(g)}$
(b) $C_3H_{8(g)} + 5O_{2(g)} \rightarrow 3CO_{2(g)} + 4H_2O_{(g)}$
(c) $C_3H_{6(g)} + H_{2(g)} \rightarrow C_3H_{8(g)}$
(d) $N_{2(g)} + 2O_{2(g)} \rightarrow 2NO_{2(g)}$

Oxidising and Reducing Agents

1. Which of the following is a redox reaction?

   A $NaOH + HCl \rightarrow NaCl + H_2O$
   B $Zn + 2HCl \rightarrow ZnCl_2 + H_2$
   C $NiO + 2HCl \rightarrow NiCl_2 + H_2O$
   D $CuCO_3 + 2HCl \rightarrow CuCl_2 + H_2O + CO_2$

2. During a redox process in acid solution, iodate ions, $IO_3^-{}_{(aq)}$, are converted into iodine, $I_{2\ (aq)}$.
   $IO_3^-{}_{(aq)} \rightarrow I_{2\ (aq)}$

   The numbers of $H^+{}_{(aq)}$ and $H_2O_{(l)}$ required to balance the ion-electron equation for the formation of 1 mol of $I_{2(aq)}$ are, respectively

   A 6 and 3
   B 3 and 6
   C 12 and 6
   D 6 and 12

3. Iodide ions can be oxidised using acidified potassium permanganate solution. The equations are:

   $2I^-{}_{(aq)} \rightarrow I_{2(aq)} + 2e^-$
   $MnO_4^-{}_{(aq)} + 8H^+(aq) + 5e^- \rightarrow Mn^{2+}{}_{(aq)} + 4H_2O_{(l)}$

   How many moles of iodide ions are oxidised by one mole of permanganate ions?
   A 1.0
   B 2.0
   C 2.5
   D 5.0

4. What is the significance of the acronym ‘OILRIG’ when explaining a redox process.

5. What is meant by a spectator ion?

6. For the following displacement reactions write down the relevant ion-electron equations and use them to work out the redox equation. Do not include the spectator ions.

   (a) copper metal reacts with silver(I) nitrate solution to form copper (II) nitrate solution and silver.

   (b) chromium metal reacts with nickel (II) sulphate solution to form chromium (III) sulphate solution and nickel.

(c) magnesium metal displaces aluminium from aluminium (III) oxide.

(d) copper is displaced from a solution of copper (II) sulphate by sodium metal.

7. Give the names of two strong oxidising agents and give two uses of each.

8. The ion-electron equations below represent the reduction and oxidation reactions which take place when an acidified solution of dichromate ions react with sulphite ions.

$$Cr_2O_7^{2-}(aq) + 14H^+(aq) + 6e^- \longrightarrow 2Cr^{3+}(aq) + 7H_2O(l)$$
$$SO_3^{2-}(aq) + H_2O(l) \longrightarrow SO_4^{2-}(aq) + 2H^+(aq) + 2e^-$$

Write the REDOX equation for this reaction.

9. Sulphur dioxide is added to wine as a preservative. A mass of 20 to 40 mg of sulphur dioxide per litre of wine will safeguard the wine without affecting its taste.

(a) Describe clearly, with full experimental detail, how 0.05 mol l^{-1} iodine solution would be diluted to give 250 cm^3 of 0.005 mol l^{-1} solution.

(b) The equation for the reaction which takes place is:

$$SO_{2(aq)} + I_{2(aq)} + 2H_2O_{(l)} \rightarrow 4H^+(aq) + SO_4^{2-}{}_{(aq)} + 2I^-{}_{(aq)}$$

(i) The indicator used in this reaction causes a change from blue to colourless at the end point. Name a substance which could be used as this indicator.

(ii) Write the ion-electron equation for the reduction reaction taking place.

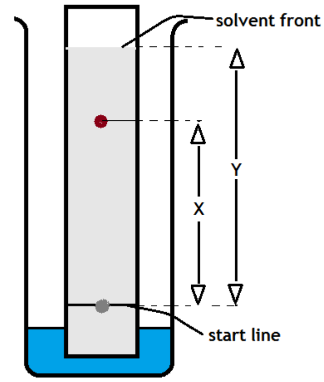
10. (a) In acid solution, iodate ions, $IO_3^-{}_{(aq)}$, are readily converted into iodine. Write an ion-electron equation for this half-reaction.

(b) Use the equation to explain whether the iodate ion is an oxidizing or a reducing agent.

Chromatography

1. Use the diagram showing a paper chromatography experiment to define the following terms:

   (a) mobile phase
   (c) stationary phase
   (d) Rf value



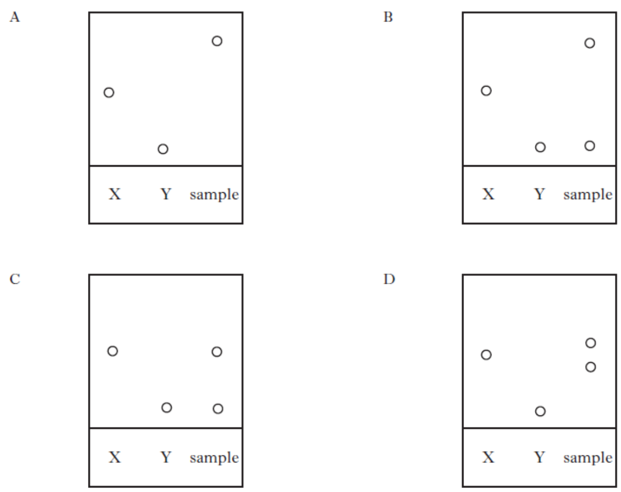
2. Compare and explain the speed at which the following move up the paper in paper chromatography.

   (a) Large molecules compared with small molecules.
   (b) A polar solvent compared with a non-polar solvent.

3. An organic chemist is attempting to synthesise a fragrance compound by the following chemical reaction.

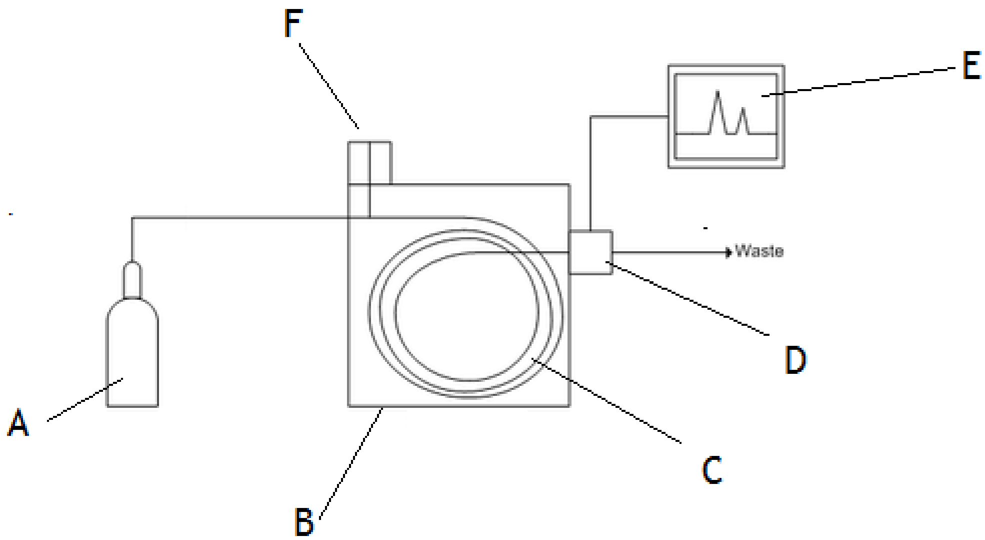
   compound X + compound Y → fragrance compound

   After one hour, a sample is removed and compared with pure samples of compounds **X** and **Y** using thin-layer chromatography.
   Which of the following chromatograms shows that the reaction has produced a pure sample of the fragrance compound?



4. Describe how chromatography can be used to identify the amino acids that make up a protein.

5. Label the parts A – F on the gas chromatography equipment below:



6. In terms of gas liquid chromatography

(a) what is the mobile phase?
(b) what is the stationary phase?
(c) why is the injection port heated?
(d) explain what is meant by retention time.

7. Give 3 different uses of gas liquid chromatography.

8. (a) Which gases are usually used as carrier gases in gas chromatography?

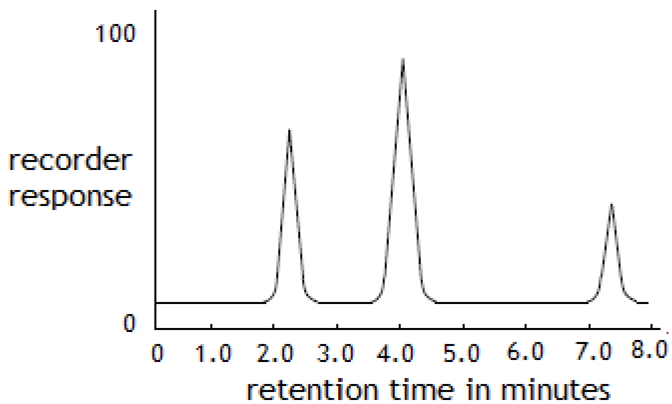
(b) Explain why these particular gases are used.

9. If the stationary phase in gas chromatography is non-polar, how would the retention times of polar and non-polar samples in the column compare to each other?

10. A technician analyses a mixture of hydrocarbons using gas chromatography.
She first calibrates the equipment using standard hydrocarbons. The retention times of these hydrocarbons are shown in the table.

hydrocarbon	formula	retention time in minutes
methane	CH_4	1.7
ethane	C_2H_6	2.2
propane	C_3H_8	3.5
butane	C_4H_{10}	4.0
pentane	C_5H_{12}	7.4

The technician then analyses the mixture of hydrocarbons. The recorder print out from this analysis is shown below.



(a) How does the recorder print out show that butane has the highest concentration?
(b) Use data in the table to draw a conclusion relating the formula of each hydrocarbon to its retention time.

Volumetric Analysis

1. 25 cm^3 of a solution of sodium hydroxide was added to a flask and titrated with a 0.2 mol l^{-1} solution of hydrochloric acid.

   $HCl + NaOH \rightarrow NaCl + H_2O$

   The experiment was carried out three times and the volumes of HCl titrated in each experiment are shown in the table.

Titration	Volume of 0.2 mol l^{-1} solution of HCl (cm^3)
1	11.3
2	10.4
3	10.6

   Calculate the concentration of the NaOH solution in mol l^{-1}.

2. 20 cm^3 of a solution of potassium hydroxide was added to a flask and titrated with a 0.1 mol l^{-1} solution of hydrochloric acid.

   $HCl + KOH \rightarrow KCl + H_2O$

   The experiment was carried out three times and the volumes of HCl titrated in each experiment are shown in the table.

Titration	Volume of 0.2 mol l^{-1} solution of HCl (cm^3)
1	20.6
2	19.9
3	20.0

   Calculate the concentration of the KOH solution in mol l^{-1}.

3. 10 cm^3 of a solution of KOH was added to a flask and titrated with a 0.05 mol l^{-1} solution of H_2SO_4.

   $H_2SO_4 + 2KOH \rightarrow K_2SO_4 + 2H_2O$

   The experiment was carried out three times and the volumes of HCl titrated in each experiment are shown in the table.

Titration	Volume of 0.2 mol l^{-1} solution of HCl (cm^3)
1	15.9
2	15.2
3	15.3

   Calculate the concentration of the KOH solution in mol l^{-1}.

4. Rhubarb leaves contain oxalic acid, $(COOH)_2$. A pupil found that it required 17 cm^3 of 0.001 mol l^{-1} of sodium hydroxide to neutralise 25 cm^3 of a solution made from rhubarb leaves. Calculate the concentration of oxalic acid in the solution given that the equation for the reaction is:

$$(COOH)_2 + 2NaOH \rightarrow Na_2(COO)_2 + 2H_2O$$

5. Acidified potassium permanganate can be used to determine the concentration of hydrogen peroxide solution; the solutions react in the ratio of

2 mol of potassium permanganate: 5mol of hydrogen peroxide.

In an analysis it is found that 16.8 cm^3 of 0.025 mol l^{-1} potassium permanganate reacts exactly with a 50 cm^3 sample of hydrogen peroxide solution. What is the concentration, in mol l^{-1} of the hydrogen peroxide solution?

6. Iodine reacts with thiosulphate ions as follows:

$$I_2(aq) + 2S_2O_3^{2-}(aq) \longrightarrow 2I^-(aq) + S_4O_6^{2-}(aq)$$

In an experiment it was found that 1.2×10^{-5} mol of iodine reacted with 3.0 cm^3 of the sodium thiosulphate solution. Use this information to calculate the concentration of the thiosulphate solution in mol l^{-1}.

7. Vitamin C, $C_6H_8O_6$, is a powerful reducing agent. The concentration of vitamin C in a solution can be found by titrating it with a standard solution of iodine, using starch as an indicator. The equation for the reaction is:

$$C_6H_8O_6(aq) + I_2(aq) \longrightarrow C_6H_6O_6(aq) + 2H^+(aq) + 2I^-(aq)$$

A vitamin C tablet was crushed and dissolved in some water. The solution was then transferred to a standard 250 cm^3 flask and made up to the 250 cm^3 mark with distilled water.
In one investigation it was found that an average of 29.5 cm^3 of 0.02 mol l^{-1} iodine solution was required to react completely with 25.0 cm^3 of vitamin C solution.
Use this result to calculate the mass, in grams, of vitamin C in the tablet.

8. Hydrogen sulfide, H_2S, can cause an unpleasant smell in water supplies. The concentration of hydrogen sulfide can be measured by titrating with a chlorine standard solution.
The equation for the reaction taking place is

$$4Cl_{2(aq)} + H_2S_{(aq)} + 4H_2O_{(l)} \rightarrow SO_4^{2-}{}_{(aq)} + 10H^+{}_{(aq)} + 8Cl^-{}_{(aq)}$$

50·0 cm^3 samples of water were titrated using a 0·010 mol l^{-1} chlorine solution.

(a) Name an appropriate piece of apparatus which could be used to measure out the water samples.

(b) What is meant by the term standard solution?

(c) An average of 29·4 cm^3 of 0·010 mol l^{-1} chlorine solution was required to react completely with a 50·0 cm^3 sample of water. Calculate the hydrogen sulfide concentration, in mol l^{-1}, present in the water sample. Show your working clearly.

9. A compound known as ethylenediaminetetraacetic acid(EDTA) is useful for measuring the quantities of certain metal ions in solution. For example, Ca^{2+} ions and EDTA react in a 1 mol:1 mol ratio.

It is found that 14.6 cm^3 of 0.1 mol l^{-1} EDTA reacts exactly with a 25cm^3 sample of a solution containing Ca^{2+} ions.

Calculate the concentration, in mol l^{-1}, of the calcium ion solution.