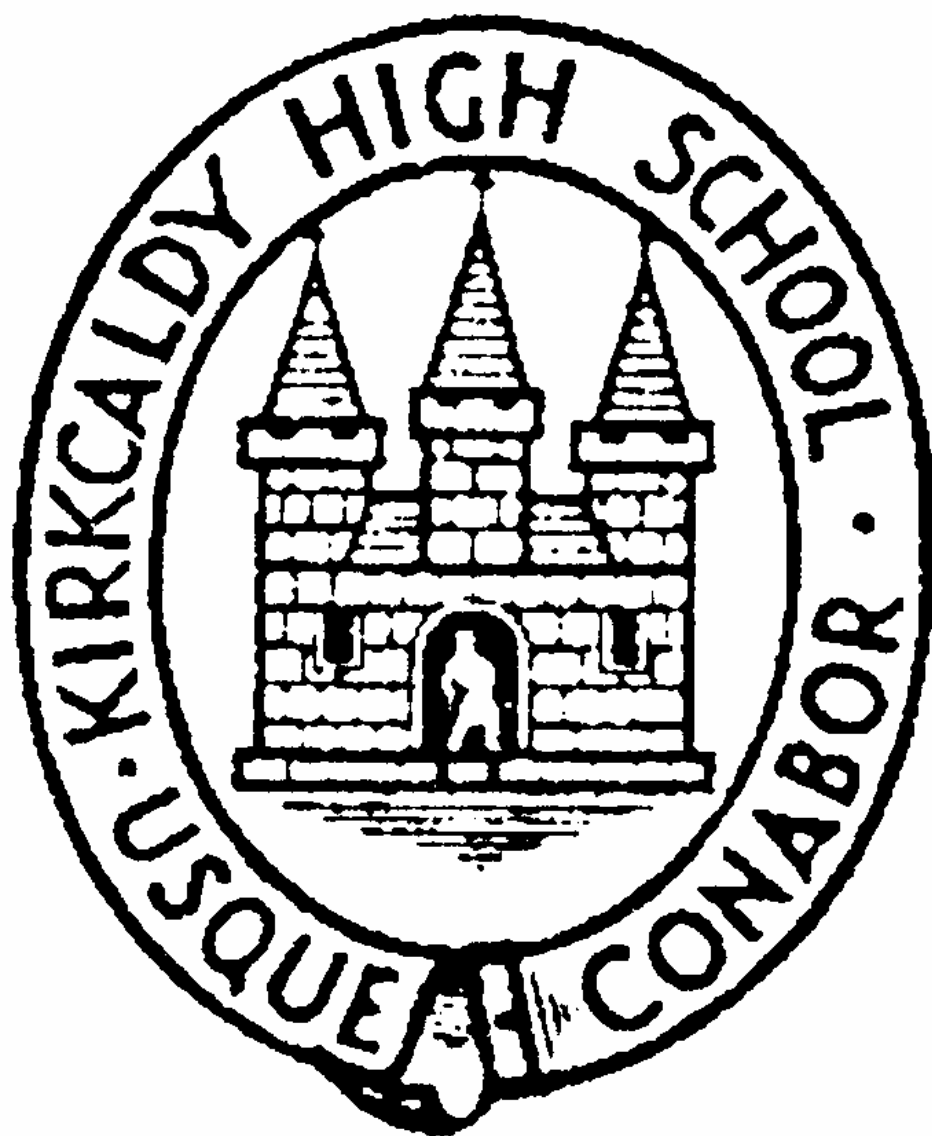


# Higher Chemistry

Unit 1 – Chemical Changes and Structure

*Homework Booklet*



Kirkcaldy High School

## Controlling the Rate of Reaction

1. A pupil made the following observations on dripping taps.  $45\text{cm}^3$  of water was collected from Tap A in 3 minutes.  $340\text{cm}^3$  of water was collected from Tap B in 20 minutes. By calculating the average rate of loss of water from each tap, find out which tap was dripping faster.
2. A farmer records the weight of his pigs every Monday. Here is part of the record for one of the pigs.

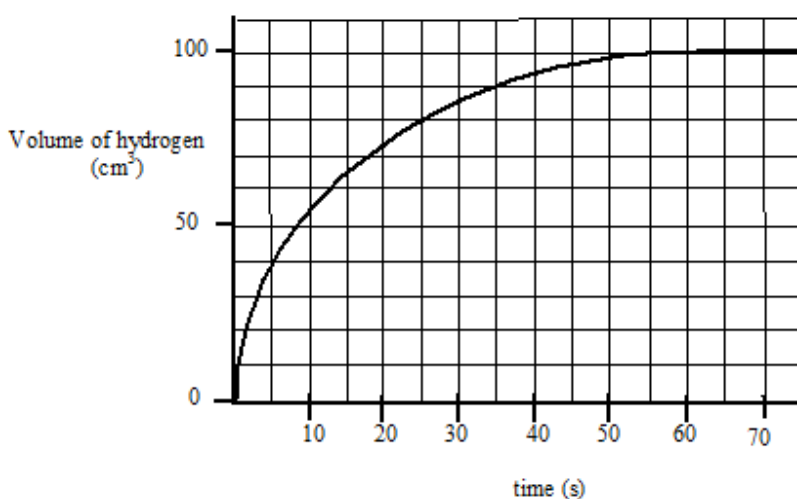
| Date   | Weight (kg) | Date   | Weight (kg) |
|--------|-------------|--------|-------------|
| Jan 1  | 75.85       | Jan 22 | 83.70       |
| Jan 8  | 76.50       | Jan 29 | 86.90       |
| Jan 15 | 79.10       | Feb 5  | 92.10       |

Calculate the average rate of weight gain per week:-

- i) during the first week
- ii) during the first three weeks
- iii) over the five week period

3. A pupil was attempting to measure the rate of a chemical reaction which produced a gas. After six seconds  $8\text{cm}^3$  of gas had been collected. After ten seconds the total volume of gas collected was  $14\text{cm}^3$ . Calculate the average rate of the reaction during this time interval (from six to ten seconds).

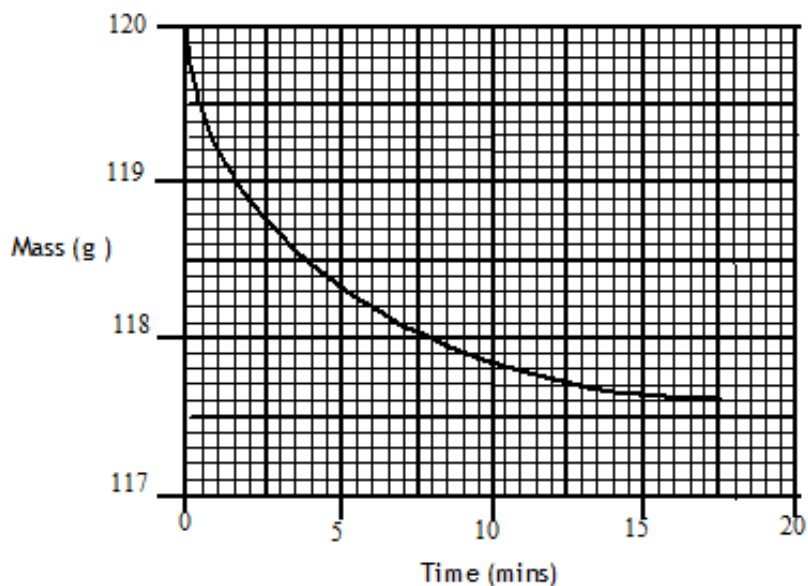
4. The graph below shows the volume of hydrogen gas released when a  $10\text{cm}$  strip of magnesium (mass =  $0.1\text{g}$ ) was added to  $30\text{cm}^3$  of  $1\text{mol l}^{-1}$  hydrochloric acid.



- (a) Calculate the average rate of reaction
  - i) over the first 15 seconds
  - ii) between 20 and 30 seconds
- (b) How long did it take for the reaction to stop?
- (c) The graph shows that the rate of reaction changes as the reaction proceeds. Explain why it changes in this way.

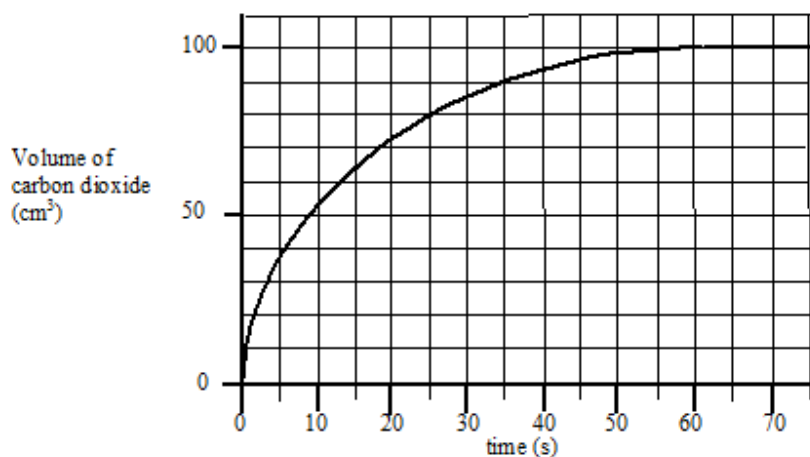
5. Marble chips (calcium carbonate), reacted with excess dilute hydrochloric acid.

The rate of reaction was followed by recording the mass of the container and the reaction mixture over a period of time. The results of the experiment are shown in the following graph.



- (a) Write a balanced equation for the reaction.
- (b) Give a reason for the loss of mass of the container.
- (c) Calculate the average rate of reaction over the first five minutes.
- (d) Why does the average rate of reaction decrease as the reaction proceeds?

6. The results shown below were obtained when 0.42 g of powdered chalk was added to 20 cm<sup>3</sup> hydrochloric acid, concentration 2 mol l<sup>-1</sup> (an excess of the acid).



- (a) Sketch the graph and add a **solid** line to the graph to show what would happen if 0.42g of chalk lumps was used instead of powdered chalk.
- (b) Add a **dotted** line to the graph to show what would happen if 20 cm<sup>3</sup> of 3 mol l<sup>-1</sup> hydrochloric acid was used instead of 2 mol l<sup>-1</sup> hydrochloric acid.

7. 1.0 g of zinc was placed in 20 cm<sup>3</sup> of 2 mol l<sup>-1</sup> hydrochloric acid.  
After 20 seconds the zinc was removed, washed, dried and re-weighed.  
The remaining zinc weighed 0.35 g.

- (a) Write a balanced chemical equation for the reaction.
- (b) Calculate the average rate of the reaction.
- (c) Calculate the number of moles of hydrochloric acid used up in the 20 seconds.

8. A pupil was investigating the effect of temperature on the rate of a chemical reaction and obtained the following data.

|                                 |     |      |    |      |      |
|---------------------------------|-----|------|----|------|------|
| Temperature (°C)                | 15  | 25   | 33 | 37   | 44   |
| Time for reaction to finish (s) | 154 | 66.7 | 40 | 30.3 | 22.2 |
| Relative rate ( ..... )         |     |      |    |      |      |

(a) Copy the table and calculate the relative rate of reaction at each temperature and add them to the table, putting the correct units in the brackets.

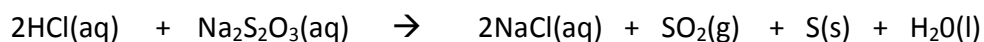
(b) Plot a graph of relative rate against temperature.

(c) Predict what the **relative rate** of the reaction will be at 50 °C.

(d) Use the graph to estimate the **time** for the reaction to finish at 40 °C.

9. (a) Explain
- i) Why decreasing the particle size increases the rate of a chemical reaction.
  - ii) Why increasing the concentration speeds up a chemical reaction.
- (b) Give an everyday example of a reaction speeded up by
- i) decreasing the particle size
  - ii) increasing the concentration

10. When hydrochloric acid is added to a solution of sodium thiosulphate the following reaction takes place.



Solid sulphur forms in the solution.

In one set of experiments the effect of varying the concentration of sodium thiosulphate was studied. Some of the volumes of solutions used are shown.

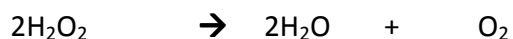
| Volume of $0.05 \text{ mol l}^{-1}$<br>$\text{Na}_2\text{S}_2\text{O}_3(\text{aq}) / \text{cm}^3$ | Volume of water/ $\text{cm}^3$ | Volume of $0.1 \text{ mol l}^{-1}$<br>$\text{HCl}(\text{aq}) / \text{cm}^3$ | Reaction time /s |
|---|--------------------------------|---|------------------|
| 200   | 0                              | 5   | 20               |
| 160   |                                |   | 25               |
| 120   |                                |   | 33               |
| 80  |                                |   | 50               |
| 40  |                                |   | 100              |

(a) Copy and then complete the table to show the volumes of water and acid that would have been used.

(b) Describe how the reaction time could have been measured.

(c) Describe how the relative rate of reaction would be obtained from each of the results.

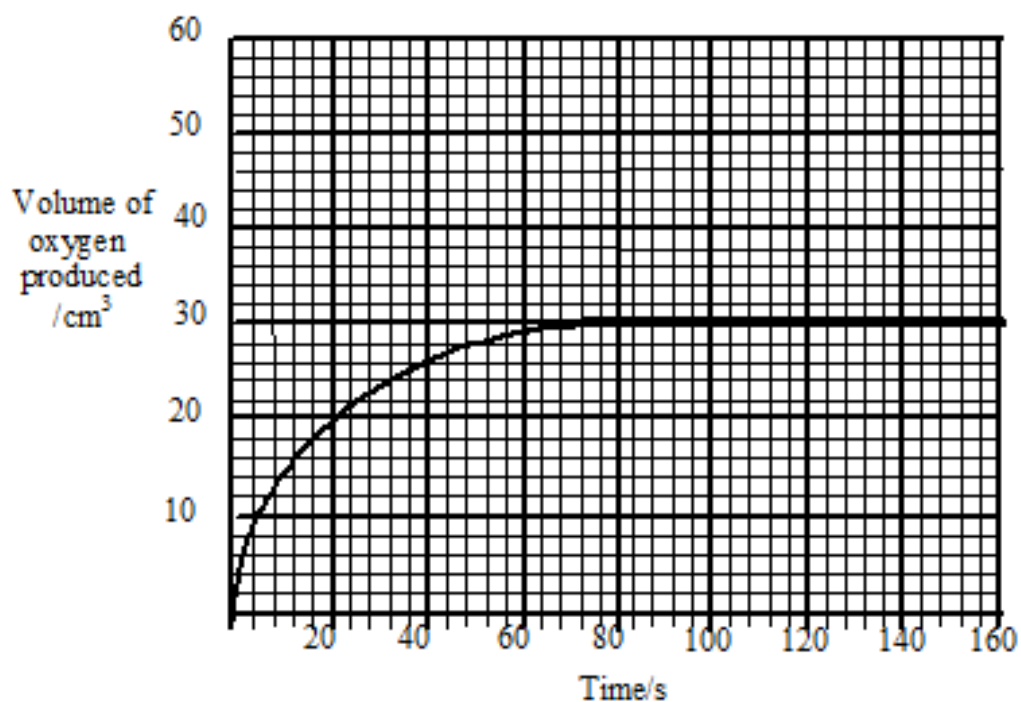
11. Hydrogen peroxide can be used to clean contact lenses. In this process, the enzyme catalase is added to break down hydrogen peroxide. The equation for the reaction is:



The rate of oxygen production was measured in three laboratory experiments using the same volume of hydrogen peroxide at the same temperature.

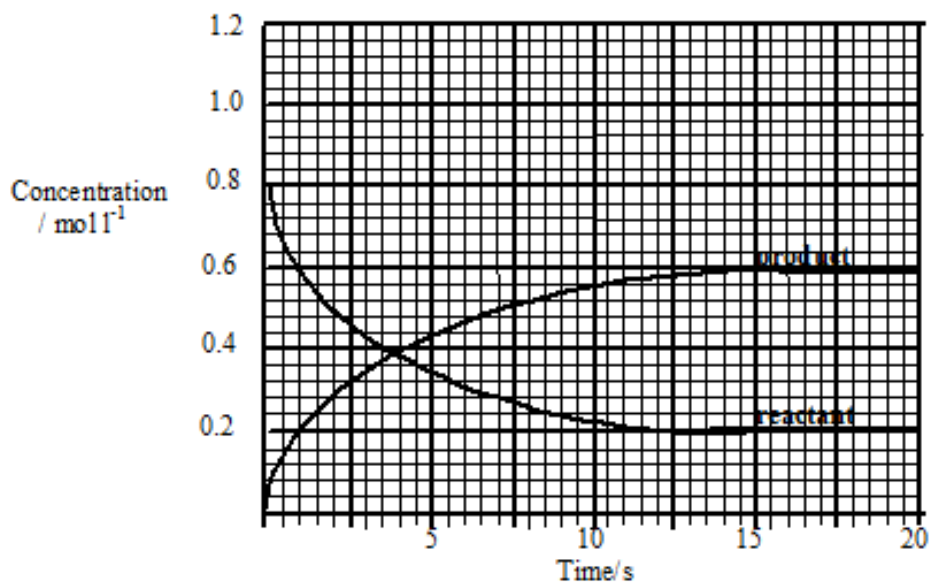
| Experiment | Concentration of $\text{H}_2\text{O}_2/\text{mol l}^{-1}$ | Catalyst used |
|------------|---|---------------|
| <b>A</b>   | 0.2   | yes           |
| <b>B</b>   | 0.4   | yes           |
| <b>C</b>   | 0.2   | no            |

The curve obtained for experiment **A** is shown.



- Calculate the average rate of the reaction over the first 40 s.
- Copy the graph and add curves to the graph to show the results of experiments B and C. Label each curve clearly.
- Draw a labelled diagram of assembled lab apparatus which could be used to carry out these experiments.

12. The graph shows the concentrations of reactant and product as equilibrium is established in a reaction.



- (a) average  
over the first 10 s.

Calculate the  
rate of reaction

- (b) The equilibrium constant for a reaction is given the symbol  $K$   
In this reaction  $K$  is given by:

$$K = \frac{\text{equilibrium concentration of product}}{\text{equilibrium concentration of reactant}}$$

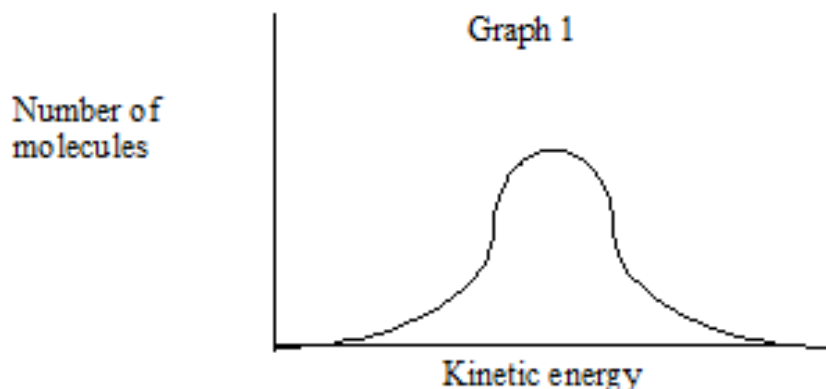
Calculate the value of  $K$  for the reaction.

- (c) The reaction is repeated using a homogeneous catalyst.

(i) What is meant by a homogeneous catalyst?

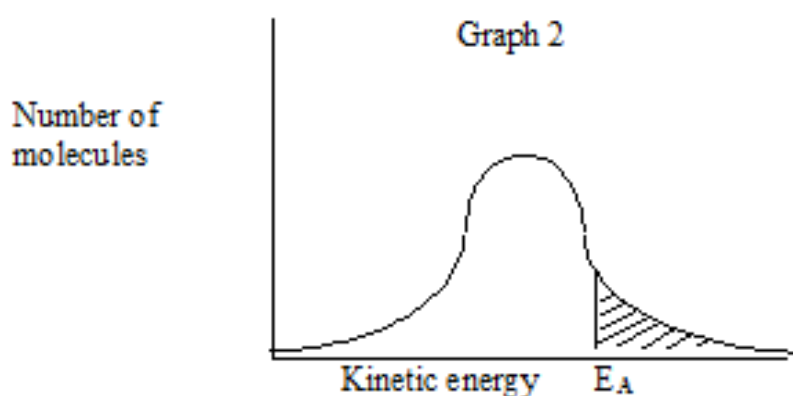
(ii) What effect would the introduction of the catalyst have on the value of  $K$ ?

13. (a) Graph 1 shows the distribution of kinetic energies of molecules in a gas at 30°C.



Copy the graph and add a dotted line to show the distribution of kinetic energies at 20°C.

(b) In Graph 2, the shaded area represents the number of molecules with the required energy of activation,  $E_A$ , for reaction to occur.



Copy the graph and draw a line to show how a catalyst affects the energy of activation.

(c) A collision involving molecules with the required energy of activation may **not** result in reaction. State a reason for this.

14. What is meant by the term “activation energy”?



15. The decomposition of an aqueous solution of hydrogen peroxide into oxygen and water can be catalysed by iodide ions,  $\text{I}^{-}(\text{aq})$ , or by solid manganese (IV) oxide,  $\text{MnO}_2(\text{s})$ .  
For each of these catalysts state, with a reason, whether the catalysis is homogeneous or heterogeneous.
16. An advice leaflet given to motorists when catalytic converters were first used states: "Cars fitted with catalytic converters must be run on unleaded petrol only."
- (a) Outline the reasons for fitting catalytic converters, naming the substances reacting and what happens to them.
- (b) Describe in terms of adsorption how catalysts work, and state the effect this has on the activation energy for the reaction.
- (c) Describe how a substance poisons a catalyst.
- (d) Explain the reason for the advice given at the start of the question.

### The Periodic Table: Bonding and Structure

17. a) Copy and complete the following statements.

i) Electronegativity is a measure of the ..... an atom in a covalent bond has for the ..... electrons of the bond.

ii) In the Periodic table electronegativity ..... across a period and ..... down a group.

b) In each of the following pairs identify the element with the greater electronegativity.

i) phosphorus or carbon

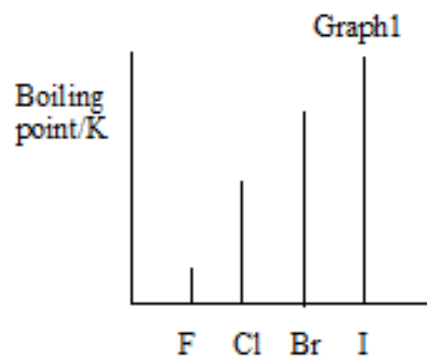
ii) silicon or nitrogen

18. All types of bonding involve electrostatic attraction between positively charged particles and negatively charged particles.

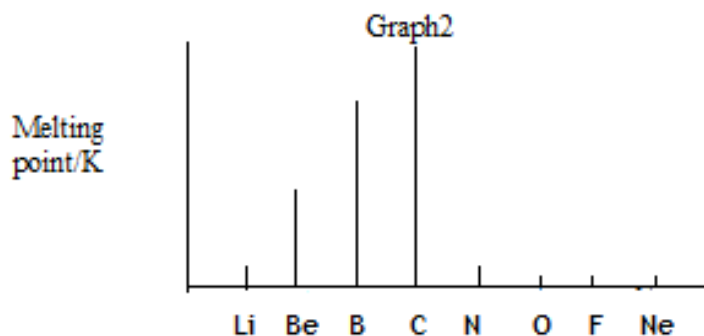
Copy and complete the table showing the three types of **strong** bonding force.

| Type of bonding | Positively charged particles | Negatively charged particles |
|-----------------|------------------------------|------------------------------|
|                 |                              | shared electrons             |
| ionic           |                              |                              |
|                 | positive nucleus             |                              |

19. a) Graph 1 shows the boiling points of the Group 7 elements. Why do the boiling points increase down Group 7?



- b) Graph 2 shows the melting points of elements from lithium to neon across the second period. Give reasons for the high melting points of boron and carbon.



20. The Periodic Table below has been divided into four sections - A, B, C and D.

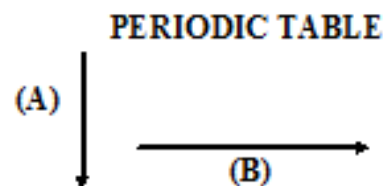
|    |    |    |    |   |   |    |    |
|----|----|----|----|---|---|----|----|
| H  |    |    |    |   |   |    | He |
| Li | Be | B  | C  | N | O | F  | Ne |
| Na | Mg | Al | Si | P | S | Cl | Ar |
| K  | Ca |    |    |   |   | Br | Kr |
| A  |    |    | B  |   | C |    | D  |

- State the type of structure in each of the four sections A, B, C and D.
- In which section(s) will van der Waals' forces between the particles be significant.
- Using elements in the above table as examples, explain briefly the difference between a covalent molecular substance and a covalent network substance.

### Trends in the Periodic Table

21. a) Which arrow (A) or (B) indicates correctly a decrease in atomic size?

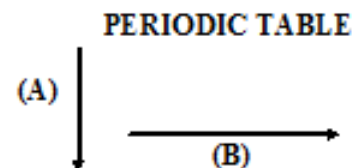
b) Explain why atomic size decreases in this way.



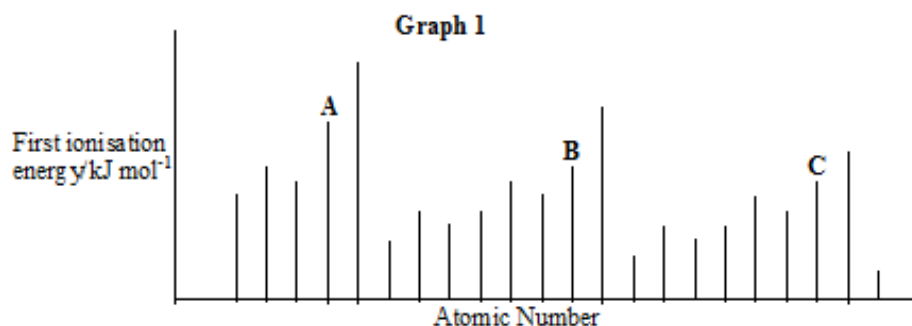
22. a) Define the **first ionization energy** of an element.

b) Which arrow (A) or (B) indicates correctly a decrease in the first ionization energy of elements?

c) Give two reasons why the ionisation energy decreases in this way.



23. The graph below shows the first ionisation energies of successive elements with increasing atomic number.



Elements A, B and C belong to the same group of the Periodic Table. Identify the group

24. Explain why the third ionisation energy of magnesium ( $7750 \text{ kJ mol}^{-1}$ ) is so much greater than the third ionisation of aluminium ( $2760 \text{ kJ mol}^{-1}$ ).

25. Ionisation energies can be found by applying an increasing voltage across test samples of gases until the gases ionise.

The results below were obtained from experiments using hydrogen atoms and then helium atoms.

| Element  | Voltage at which an atom of gas ionises/V |                   |
|----------|---|-------------------|
| hydrogen | 13.6                                      | no further change |
| helium   | 24.6                                      | 54.5              |

- a) Why are there two results for helium but only one for hydrogen?
- b) (i) Write an equation which would represent the first ionisation energy of helium gas.
- (ii) Why is the first ionisation of helium higher than that of hydrogen?
- c) The ionisation energy, I.E. , can be found from:

$$\text{I.E.} = \text{voltage} \times 1.6 \times 10^{-19} \text{ J}$$

Calculate a value for the first ionisation energy of helium.

## Bonding in Compounds

26. There are many types of attractive force, some are weak and some are strong.

|   |  |   |
|---|--|---|
| <b>A</b><br>positively charged ions and negatively charged ions | <b>B</b><br>temporary dipole and induced dipole            | <b>C</b><br>positively charged nuclei and delocalised electrons |
| <b>D</b><br>permanent dipole and permanent dipole               | <b>E</b><br>positively charged nuclei and shared electrons |   |

Identify the statement(s) referring to

- a) van der Waals' forces
- b) the forces between oxygen and hydrogen atoms in water
- c) the intermolecular forces in HCl gas.
- d) ionic bonds

27. The covalent bond in hydrogen chloride gas is polar and the molecule is polar. The covalent bonds in silicon tetrachloride are also polar. Explain why the silicon tetrachloride molecule is non-polar.

28. There are many types of bonding force between atoms and molecules.

|   |                                      |                                      |
|---|--------------------------------------|--------------------------------------|
| <b>A</b><br>permanent dipole to permanent dipole interactions | <b>B</b><br>non-polar covalent bonds | <b>C</b><br>hydrogen bonds           |
| <b>D</b><br>ionic bonds                                       | <b>E</b><br>metallic bonds           | <b>F</b><br>London dispersion forces |

- a) Identify the three forces present in hydrogen fluoride.
- b) Identify the force(s) present in
  - i) methane
  - ii) sodium chloride
  - iii) hydrogen bromide
  - iv) neon
  - v) oxygen
- c) Identify the bond(s) and/or force(s) of attraction
  - i) responsible for the low boiling point of argon.
  - ii) that can exist **between** molecules.
  - iii) that allow electrons a lot of free movement.

29. Which of the compounds below have:

|          |               |          |                            |          |                |
|----------|---------------|----------|----------------------------|----------|----------------|
| <b>A</b> | $\text{Cl}_2$ | <b>B</b> | $\text{HF}$                | <b>C</b> | $\text{NaCl}$  |
| <b>D</b> | $\text{NH}_3$ | <b>E</b> | $\text{CH}_3\text{COCH}_3$ | <b>F</b> | $\text{SiO}_2$ |

a) van der Waals' forces **only**.

b) hydrogen bonds

30. Elements and compounds show a variety of structures.

|          |                |          |               |          |                     |
|----------|----------------|----------|---------------|----------|---------------------|
| <b>A</b> | $\text{Cl}_2$  | <b>B</b> | $\text{Na}$   | <b>C</b> | $\text{NaCl}$       |
| <b>D</b> | $\text{SiO}_2$ | <b>E</b> | $\text{NH}_3$ | <b>F</b> | $\text{C(diamond)}$ |

Identify the substance(s)

a) with a tetrahedral arrangement of bonds in a covalent network.

b) which can conduct electricity because of delocalised electrons.

c) with discrete covalent molecules

31. Many of the properties of water arise from the presence of polar O - H bonds which make the water molecules polar.

Carbon dioxide contains polar C = O bonds but its molecules are non-polar.

a) Explain this difference with the aid of diagrams of each molecule, showing polarities.

b) Water is unusual in that in the solid form (ice) is less dense than the liquid form.  
Explain why water behaves in this way.

32. Both bonded and non-bonded pairs of electrons repel each other and this determines the shape of the molecule.

The following procedure is used to find the total number of pairs of electrons around a central atom.

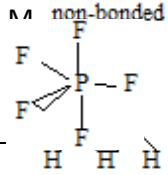
- (i) Note the number of electrons in the outer energy level (shell) of the central atom.
- (ii) Note the number of other atoms present --- each atom provides one electron for bonding.
- (iii) Add (i) and (ii) to give the total number of electrons.
- (iv) Divide this number by two to give the number of electron pairs - both bonded and non-bonded pairs.

**Example:-** with ammonia,  $\text{NH}_3$ , N is the central atom.

- (i)  $2,5 = 5$  electrons
- (ii)  $3\text{H} \quad 3 \times 1 = 3$  electrons
- (iii) Total  $= 8$  electrons
- (iv) 8 electrons gives four pairs.

Since  $\text{NH}_3$  only has 3 bonds there is one non-bonded pair. The 4 pairs of electrons repel each other, giving the pyramid shape of the ammonia molecule as shown in the first row of the table.

Copy and complete the table.

| Formula         | Outer electrons in central atom | Total number of electrons | Bonded pairs | Non-bonded pairs |  |
|-----------------|---------------------------------|---------------------------|--------------|------------------|--|
| $\text{NH}_3$   | 5                               | 8                         | 3            | 1                |  |
| $\text{CCl}_4$  | 4                               |                           | 4            | 0                |  |
| $\text{BeCl}_2$ | 2                               | 4                         | 2            |                  |  |
| $\text{PF}_5$   |                                 | 10                        | 5            |                  |  |



33.a) Predict the type of bonding (non-polar covalent, polar covalent or ionic) between the following elements.

i) magnesium and sulphur

ii) oxygen and phosphorus

iii) nitrogen and nitrogen

iv) fluorine and oxygen

b) Justify, by reference to electronegativity values, your answers to i) and iv).

34. The boiling points of compounds depend on the intermolecular forces.

| Name      | Formula  | Molecular mass | Boiling point ( $^{\circ}\text{C}$ ) |
|-----------|--|----------------|--------------------------------------|
| butane    | $\text{CH}_3\text{CH}_2\text{CH}_2\text{CH}_3$ |                | - 0.5                                |
| propanone | $\text{CH}_3\text{COCH}_3$                     |                | 56                                   |

a) Copy the table and calculate the molecular mass for each compound.

b) Explain why the boiling points are different.

35. The Group 5 hydrides are covalent compounds.

| Compound       | Enthalpy of formation/ $\text{kJ mol}^{-1}$ | Boiling point/K |
|----------------|---|-----------------|
| $\text{NH}_3$  | -46   | 240             |
| $\text{PH}_3$  | +6  | 185             |
| $\text{AsH}_3$ | +172  | 218             |

a) What is the trend in stability of the group 5 hydrides?

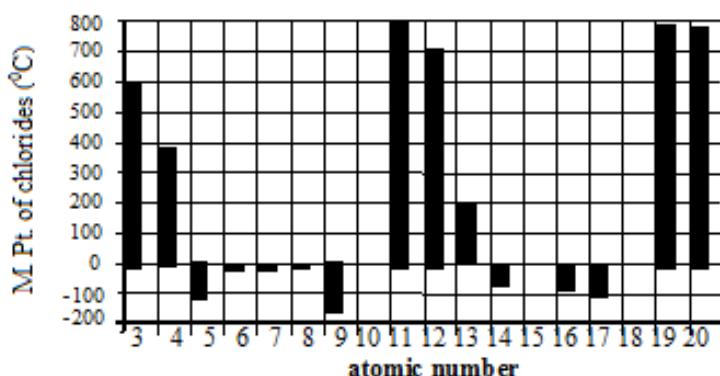
b) Explain why the boiling point of  $\text{NH}_3$  is higher than the boiling point of  $\text{PH}_3$  and  $\text{AsH}_3$ .

36. The table below shows the boiling point, molecular mass and structure of the simplest alkanol, methanol, the simplest alkanolic acid, methanoic acid and the ester methyl methanoate which forms when the acid and the alkanol react together in a condensation reaction.

| Compound          | methanol   | methanoic acid   | methyl methanoate   |
|-------------------|--|--|---|
| Structure         | $\begin{array}{c} \text{H} \\   \\ \text{H}-\text{C}-\text{O}-\text{H} \\   \\ \text{H} \end{array}$ | $\begin{array}{c} \text{O} \\    \\ \text{H}-\text{C}-\text{O}-\text{H} \end{array}$ | $\begin{array}{c} \text{O} \quad \text{H} \\    \quad   \\ \text{H}-\text{C}-\text{O}-\text{C}-\text{H} \\   \\ \text{H} \end{array}$ |
| Molecular mass    | 32   | 46   | 60  |
| Boiling point(°C) | 65   | 100  |   |

- a) Using **molecular mass** as the **only criterion**, use the boiling points of methanol and methanoic acid to predict the boiling point of methyl methanoate and put it in the table.
- b) The boiling point of the ester is in fact 32°C. Explain in terms of the intermolecular forces why this value is so different from your prediction.

37. The bar chart shows the melting points of chlorides of elements 3 to 20 (with no bars for 10, 15 and 18).



- a) Copy and complete this statement describing the pattern for these **melting points** related to the **Group number**.  
**In general** as the Group number increases the melting point of the chloride .....
- b) Explain why no values are given for elements 10 and 18.
- c) **From the bar chart**, state which of the chlorides has the weakest forces between the molecules.
- d) Predict a value for the melting point of the chloride of element 15.

38. Explain in terms of its structure and bonding why silicon carbide can be used to make stones for sharpening chisels and knives.
39. Consider the substances: potassium, bromine and potassium bromide.
- Construct a table to show the type of bonding, the structure, the solubility or reaction with water, the state at room temperature and the electrical conductivity of the three substances.
  - Explain the solubility of potassium bromide in water in terms of its bonding.
40. Lithium iodide is quite soluble in non-polar solvents e.g. white spirit (a mixture of hydrocarbons).
- What does this statement suggest about the type of bonding in lithium iodide?
  - State, with an explanation, whether you would expect lithium fluoride to be more or less soluble than lithium iodide in non-polar solvents.