The melting temperature of carbon

Target level

This exercise is suitable for either 14–16 year olds who have studied bonding and structure and can calculate relative molecular mass, or for revision with post-16 students prior to meeting these topics at an advanced level. A knowledge of temperature in kelvin (K) is required.

Topics

The relationship between structure and properties; giant covalent structures.

Rationale

It is known that students may have difficulty in distinguishing between substances with simple molecules (where the solid is held together by intermolecular forces), and those with giant covalent lattices. This problem is compounded by the convention of giving carbon allotropes the formula C (*cf* He, Ne etc), and representing the relative molecular mass (M_r) accordingly. (The melting temperature and structure used are that of diamond – to avoid the complication of the anisotropy of graphite.)

This exercise is intended to make students think about this issue, and to realize that although diamond is commonly given the formula 'C' , this should not be taken to imply it forms monatomic molecules. These ideas are discussed in Chapter 7 of the Teachers' notes.

During piloting, teachers suggested that the exercise was 'useful in making pupils think about what a formula means' and 'useful to reinforce the difference between simple and giant covalent'. Some post-16 students thought the exercise 'clarified things', but it was found too basic by others at this level.

Some students will recall that carbon (diamond or graphite) has a high melting temperature. This should not diminish the effectiveness of the exercise, as long as students recognise the general pattern in the data provided, and think about why carbon is anomalous. Similarly, it is not important whether students are already familiar with '∞' as the symbol for infinity, as long as they recognise that the formula 'C' should not be taken to imply carbon is monatomic.

The kelvin (K) is the unit of thermodynamic temperature difference. It is defined by setting the thermodynamic temperature of the triple point of water at 273.16 K above absolute thermodynamic zero.

The 'degree Celsius' as a measure of temperature difference is no longer used. It is the same size as the kelvin. The temperature difference between the freezing and boiling points of water at normal pressure on the Celsius scale (0 °C and 100 °C respectively) is therefore 100 K, since 0 °C = 273 K and 100 °C = 373 K.

Instructions

First issue the student worksheet **Predicting the melting temperature of carbon** and when this is completed, then hand out the worksheet **Explaining the melting temperature of carbon**.

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Resources

- Student worksheets
  – Predicting the melting temperature of carbon
  – Explaining the melting temperature of carbon

Feedback for students

A suggested answer sheet for teachers is provided.

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The melting temperature of carbon – answers

Predicting the melting temperature of carbon

Predicting the melting temperature of carbon

1. M_r(Ne) = 1 x 20.2 = 20.2
2. M_r(Cl_2) = 2 x 35.5 = 71.0
3. M_r(C) = 1 x 12.0 = 12.0
4. Students should recognise that in the examples given melting temperature increases with relative molecular mass.
5. The students should predict a melting temperature greater than 4K and less than 25K – and explain that they have selected an estimate to have a higher melting temperature than helium, and a lower melting temperature than neon.

(Experience from the pilot suggests that some students may provide quite precise estimates based on various algebraic manipulations of subsets of the data. It is suggested that such students could be asked to plot a graph, and comment on the reliability of their estimate.)

Explaining the melting temperature of carbon

The students should enter (in the box at the top of the page) the same predictions that they have given on the previous sheet.

If the prediction was in line with the data provided, (*eg* 10–20 K) then they should tick the box labelled 'a long way out'.

1. The diagrams should help explain the melting temperature of carbon because:

   unlike the other examples (neon, chlorine and sulfur) carbon does not comprise of separate (*ie* discrete) molecules, but a large (*ie* extensive) structure (lattice). Melting carbon requires breaking covalent bonds - not just overcoming intermolecular forces.

2. Giant covalent is meant to suggest:

   that the structure of carbon comprises of a very large number of units all interconnected through strong covalent bonds.

3. The symbol ∞ is meant to suggest either that the structure may be considered as effectively infinite or that a single carbon atom should not be considered to be a molecule of carbon.

Predicting the melting temperature of carbon

Introduction

Part of doing science involves spotting patterns, and making predictions which can be tested by experiments. In this exercise you will be asked to make a prediction based on information you will be given. It is not important whether your prediction is correct, as long as it is based on the information given.

Information about some elements

This section is to make sure you remember what is meant by the relative molecular mass of an element.

Many substances are said to be 'molecular' - they are comprised of vast numbers of separate identical particles. The name given to the tiny particles in these substances is molecules. Usually a molecule can be thought of as several atoms bonded together. In a few substances the molecules are single atoms. Often these substances are called atomic substances.

The formula of helium is He. It consists of single atoms. The relative atomic mass of helium, A_r(He), is 4.0, and its relative molecular mass, M_r(He), is also 4.0.

The formula of fluorine is F_2. It has molecules that can be thought of as two atoms bonded together. The relative atomic mass of fluorine, A_r (F), is 19.0, and its relative molecular mass, M_r (F_2), is therefore 38.0.

The formula of sulfur is S_8. It has molecules that can be thought of as eight atoms bonded in a ring arrangement. The relative atomic mass of sulfur, A_r(S), is 32.1, and its relative molecular mass, M_r(S_8), is therefore 256.8.

1. The formula of neon is Ne. It consists of single atoms. The relative atomic mass of neon, A_r(Ne) is 20.2. What is the relative molecular mass of neon?

   M_r(Ne) = ____________

2. The formula of chlorine is Cl_2. It has molecules that that can be thought of as two atoms bonded together. The relative atomic mass of chlorine, A_r(Cl), is 35.5. What is the relative molecular mass of chlorine?

   M_r(Cl_2) = ____________

3. The formula of carbon is C. The relative atomic mass of C is 12.0. What do you think the relative molecular mass of carbon will be?

   M_r(C) = ____________

The table below shows the melting temperatures (in Kelvin, K) of some elements.

Element	M_r	Melting temperature/K
Helium (He)	4.0	4
Carbon (C)	12.0	
Neon (Ne)	20.2	25
Fluorine (F_2)	38.0	53
Chlorine (Cl_2)	71.0	172
Bromine (Br_2)	159.8	266
Iodine (I_2)	253.8	387
Sulphur (S_8)	256.8	392

It has been suggested that there is a general relationship between the relative molecular mass of an element, and the temperature at which the solid element melts.

4. Can you see any relationship in the data given in the table? Describe any pattern you can see:

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The melting temperature of carbon is not given in the table.

5. Predict the (approximate) melting temperature for carbon? Make an estimate, and explain your reasons:

Solid carbon will melt at about __________________

I think this because

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Now ask your teacher for the second set of sheets.

Explaining the melting temperature of carbon

Write your prediction of the approximate melting temperature of carbon in the box below.

Prediction: about __________ K

This is your prediction based upon the data you were given. In science it is important to make predictions, because while testing the predictions we are also testing the ideas we use to explain things. Often when our predictions are wrong it helps us find better ways of understanding things.

Experiments show that solid carbon is difficult to melt and only changes into a liquid at a very high temperature. The melting temperature of carbon is 3823K. How close was your prediction? (tick one box)

❑ just about right ❑ a little bit out ❑ a long way out

On the separate sheet you will find four diagrams showing the particles in neon, chlorine, sulfur and carbon. It is not possible to draw accurate diagrams to show exactly what atoms and molecules are like. These picture are very simple models of how scientists sometimes think about these particles.

Look at the four diagrams, and use them to help you answer the following questions:

1. Do the diagrams help you understand why carbon has such a high melting temperature? (Explain your answer.)

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2. Scientists sometimes describe carbon as having a giant covalent structure. What do you think is meant by giant covalent?

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3. It is sometimes suggested that the symbol for the carbon macromolecule should be C_{∞} rather than just C. What do you think the ∞ symbol is meant to show in C_{∞}?

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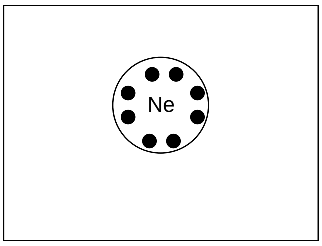
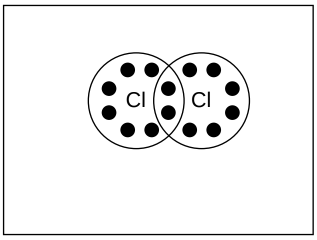
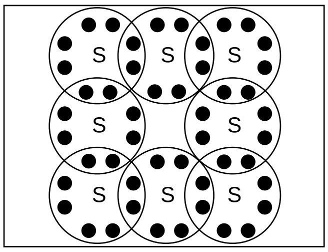
The following diagrams show how scientists picture particles of neon (Ne), chlorine (Cl), sulfur (S) and carbon (C).



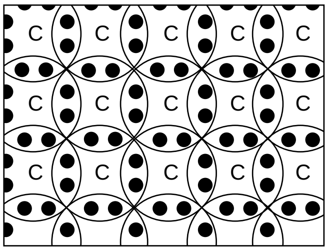
A neon atom, Ne



A chlorine molecule, Cl_2



A sulfur molecule, S_8



Part of the giant covalent structure of carbon C or C_∞

(There are many ways of drawing atoms and molecules - and we choose a type of diagram depending on which aspects we are interested in. For example, the diagrams above show the particles as flat. Molecules are not flat, but the shapes of the molecules were not important in this particular piece of work. At another time it might be important to show the shapes of the molecules.)

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