2.2 Bonding and Structure: Test Pack

AQA 7405 · Calculator allowed · about 85 minutes

Total Marks

Name: _____ Date: ____ / ____ / _____

Answer ALL questions. Show all your working.

1 This question is about ionic bonding and the properties of ionic compounds, using sodium chloride, NaCl, as an example.

(a) Define the term ionic bonding. **(1)**

(b) Describe the structure formed by sodium chloride. **(2)**

(c) Explain why sodium chloride has a high melting point. **(3)**

(d) Explain why solid sodium chloride does not conduct electricity, but molten sodium chloride does. **(3)**

(e) Ionic radii: Na^+ = 102 pm, Cl^- = 181 pm, Mg^{2+} = 72 pm, O^{2-} = 140 pm. Predict, giving a reason, whether magnesium oxide, MgO, will have a higher or lower melting point than sodium chloride. **(2)**

(Total for Question 1 is 11 marks)

© Revision Library | revisionlibrary.co.uk

2 A student, Priya, investigates the structure and bonding of four unknown solid substances, P, Q, R and S, by measuring their melting points and testing their electrical conductivity and solubility. This tests key required practical skills: safe use of heating apparatus, and using experimental data to classify substances by structure and bonding.

Table 1: physical properties of four unknown solid substances

Substance	Melting point / C	Conducts as a solid?	Conducts when molten?	Soluble in water?	Soluble in hexane?
P	801	No	Yes	Yes	No
Q	1085 (malleable solid)	Yes	Yes	No	No
R	180 (decomposes above 250 C, releasing a toxic gas)	No	No	No	Yes
S	1610	No	No	No	No

(a) Describe how Priya should use an electrothermal (electric) melting point apparatus to determine the melting point of a solid sample safely and accurately. **(3)**

(b) Substance R decomposes above 250 C, releasing a toxic gas. State one safety precaution Priya should take when heating substance R. **(1)**

(c) Using the data in Table 1, identify the type of structure and bonding present in each of substances P, Q, R and S, justifying each conclusion using at least two pieces of data. **(8)**

(d) Priya's determined melting point for P was 802 C. The accepted literature value is 801 C. Calculate the percentage error in Priya's result. **(2)**

(e) Explain why it is necessary to test the electrical conductivity of both the solid and the molten states of a substance in order to distinguish an ionic compound from a metal. **(3)**

© Revision Library | revisionlibrary.co.uk

(f) Suggest one improvement Priya could make to her method for determining melting point that would increase the reliability of her results. **(2)**

(g) A second student, Jamal, repeats the conductivity test on substance S and obtains an anomalous result showing conduction. Suggest two possible reasons for this anomaly. **(2)**

(Total for Question 2 is 21 marks)

---

3 This question is about electronegativity, bond polarity and molecular dipoles.

(a) Pauling electronegativity values: H = 2.1, C = 2.5, N = 3.0, O = 3.5, F = 4.0, Na = 0.9, Mg = 1.2, Cl = 3.0. Calculate the electronegativity difference for each of the following bonds: Na-Cl, C-Cl, C-H, O-H. **(4)**

(b) Using the general guide that a difference of 0.4 or less indicates an essentially non-polar covalent bond, a difference of more than 0.4 and up to 1.8 indicates a polar covalent bond, and a difference above 1.8 indicates a bond that is best described as ionic, classify each of the four bonds in (a). **(4)**

(c) Methane, CH_4, and tetrachloromethane, CCl_4, both have no overall (net) molecular dipole moment, even though CCl_4 contains polar C-Cl bonds. Explain why. **(1)**

(Total for Question 3 is 9 marks)

© Revision Library | revisionlibrary.co.uk

4 This question is about ionic polarisation and covalent character in Group 2 chlorides.

(a) State Fajans' rules for predicting when an ionic bond will have significant covalent character, in terms of the cation and the anion involved. **(3)**

(b) Ionic radii: Be^{2+} = 45 pm, Mg^{2+} = 72 pm, Cl^- = 181 pm. Using the data given and Fajans' rules, predict which chloride, $BeCl_2$ or $MgCl_2$, has the greater degree of covalent character in its bonding. Explain your answer. **(3)**

(c) Predict, giving a reason, which of $BeCl_2$ and $MgCl_2$ has the lower melting point. **(3)**

(Total for Question 4 is 9 marks)

---

5 This question uses boiling point data for the halogens to explore trends in intermolecular forces and the limitations of extrapolation.

(a) Boiling points: F_2 (Mr = 38) = -188°C, Cl_2 (Mr = 71) = -34°C, Br_2 (Mr = 160) = 59°C, I_2 (Mr = 254) = 184°C. State and explain the trend in boiling point from F_2 to I_2. **(3)**

(b) At2 has Mr = 420 (approximately). Using the gradient between the Br_2 and I_2 data points, estimate the boiling point of At2. **(3)**

(c) Suggest why extrapolating this trend to estimate the boiling point of At2 may be unreliable. **(2)**

(Total for Question 5 is 8 marks)

© Revision Library | revisionlibrary.co.uk

Mark scheme · 2.2 Bonding and Structure: Test Pack

Question 1

(a) the electrostatic force of attraction between oppositely charged ions oe **B1**

(a) Answer: The electrostatic force of attraction between oppositely charged ions.

(b) a giant ionic lattice (giant structure) oe **B1**

(b) a regular, repeating three-dimensional arrangement of alternating Na^+ and Cl^- ions oe **B1**

(b) Answer: A giant ionic lattice: a regular, repeating 3-D arrangement of alternating Na^+ and Cl^- ions.

(c) NaCl has a giant ionic lattice held together by strong electrostatic forces of attraction between oppositely charged ions oe **M1**

(c) these forces act in all directions throughout the lattice (many strong ionic bonds must be broken) oe **A1**

(c) a large amount of (thermal) energy is needed to overcome these strong forces, so the melting point is high oe **A1**

(c) Answer: NaCl has a giant ionic lattice with strong electrostatic attractions acting throughout the structure; a large amount of energy is needed to overcome these, giving a high melting point.

(d) in the solid, the ions are held in fixed positions in the lattice (only vibrate about a fixed point) and are not free to move oe **B1**

(d) with no mobile charge carriers, solid NaCl cannot conduct electricity oe **B1**

(d) when molten, the lattice breaks down and the ions become free to move, so they can carry charge and conduct electricity oe **B1**

(d) Answer: In the solid, ions are fixed in the lattice and cannot move to carry charge. When molten, ions are free to move, so molten NaCl conducts.

(e) predicts MgO has a higher melting point than NaCl **B1**

(e) correct reason: MgO ions have greater charge (2+ and 2-, compared with 1+ and 1- in NaCl) and/or smaller ionic radii (ions closer together), so the electrostatic force of attraction between the ions is stronger oe **B1**

(e) Answer: MgO has a higher melting point than NaCl, because its ions have greater charge and smaller radii, giving stronger electrostatic attraction.

Question 2

(a) grinds the solid to a fine powder and packs a small amount into a (sealed) capillary tube oe **B1**

(a) heats the sample slowly and at a controlled/reduced rate (e.g. no more than about 1-2 C per minute) as the temperature approaches the expected melting point, observing the sample closely oe **B1**

(a) records the temperature range over which the solid starts to melt and finishes melting (the melting point), and repeats with a fresh sample to check reproducibility oe **B1**

(a) Answer: Grind the solid, pack into a sealed capillary tube, heat slowly (especially near the expected melting point) while observing, and record the melting range; repeat for reproducibility.

(b) carry out the heating in a fume cupboard (or use a similarly effective means of avoiding inhalation of the toxic gas) oe **B1**

(b) Answer: Heat substance R in a fume cupboard.

(c) P: identifies (giant) ionic lattice **B1**

(c) P: justifies using at least two data points, e.g. conducts only when molten (ions become mobile) and is soluble in water/has a high melting point oe **B1**

(c) Q: identifies giant metallic lattice **B1**

(c) Q: justifies using at least two data points, e.g. conducts as both a solid and a liquid (delocalised electrons present in both states) and is malleable oe **B1**

(c) R: identifies simple molecular structure **B1**

(c) R: justifies using at least two data points, e.g. low melting point/decomposes rather than surviving to a high temperature (weak intermolecular forces) and does not conduct/soluble in non-polar hexane oe **B1**

(c) S: identifies giant covalent (macromolecular) structure **B1**

(c) S: justifies using at least two data points, e.g. very high melting point (strong covalent bonds throughout the lattice) and does not conduct/insoluble in both solvents oe **B1**

(c) Answer: P: giant ionic. Q: giant metallic. R: simple molecular. S: giant covalent (macromolecular).

(d) percentage error = (|802-801| / 801) x 100 **M1**

(d) = 0.12% (accept awrt 0.1-0.13%) cao **A1**

(d) Answer: 0.12% (accept awrt 0.1-0.13%)

(e) an ionic solid does not conduct electricity because its ions are held in fixed positions in the lattice and are not free to move oe **B1**

(e) an ionic compound only conducts when molten, because the lattice breaks down and the ions become free to move and carry charge oe **B1**

(e) a metal conducts electricity in both the solid and molten states, because its delocalised electrons are always free to move, regardless of state; testing both states therefore distinguishes the two bonding types oe **B1**

(e) Answer: Ionic solids do not conduct (ions fixed) but conduct when molten (ions mobile); metals conduct in both states (delocalised electrons always mobile), so testing both states distinguishes ionic compounds from metals.

(f) identifies a valid improvement, e.g. repeat the determination using at least two further fresh samples and calculate a mean melting point, or reduce the heating rate further as the expected melting point is approached oe **B1**

(f) correct reasoning: repeating and averaging reduces the effect of random error/anomalous readings, or a slower heating rate gives a narrower, more precise melting range oe **B1**

(f) Answer: Repeat the determination with fresh samples and calculate a mean, to reduce the effect of random error.

(g) identifies a valid reason, e.g. the sample of S was contaminated with a conducting impurity (such as a trace of graphite, a metal, or an ionic salt) oe **B1**

(g) or the probes did not make good/consistent electrical contact with the solid surface, giving an unreliable reading oe **B1**

(g) Answer: The sample may have been contaminated with a conducting impurity, or the probes made poor contact with the solid surface.

© Revision Library | revisionlibrary.co.uk

Question 3

(a) Na-Cl: 2.1 **B1**

(a) C-Cl: 0.5 **B1**

(a) C-H: 0.4 **B1**

(a) O-H: 1.4 **B1**

(a) Answer: Na-Cl = 2.1, C-Cl = 0.5, C-H = 0.4, O-H = 1.4.

(b) Na-Cl: ionic **B1**

(b) C-Cl: polar covalent **B1**

(b) C-H: essentially non-polar covalent (accept weakly polar covalent) **B1**

(b) O-H: polar covalent **B1**

(b) Answer: Na-Cl ionic; C-Cl polar covalent; C-H (essentially) non-polar covalent; O-H polar covalent.

(c) both molecules are symmetrical (tetrahedral), so the individual bond dipoles are arranged symmetrically and cancel out (the vector sum of the bond dipoles is zero), oe **B1**

(c) Answer: The bond dipoles are arranged symmetrically in the tetrahedral molecules and cancel out.

Question 4

(a) a cation with a high charge density (a small ionic radius and/or a high charge) has strong polarising power, oe **B1**

(a) an anion with a large ionic radius is easily distorted and is described as highly polarisable, oe **B1**

(a) when a small, highly charged cation strongly polarises (distorts the electron cloud of) a large, polarisable anion, electron density is drawn into the region between the ions, giving the bond significant covalent character, oe **B1**

(a) Answer: A small, highly charged cation strongly polarising a large, polarisable anion gives a bond significant covalent character.

(b) Be^{2+} has a smaller ionic radius than Mg^{2+}, for the same ionic charge (+2) **M1**

(b) so Be^{2+} has a higher charge density and is more strongly polarising than Mg^{2+} **B1**

(b) Be^{2+} polarises the large, polarisable Cl^- ion more strongly than Mg^{2+} does, drawing more electron density into the bond, so $BeCl_2$ has the greater degree of covalent character, oe **B1**

(b) Answer: $BeCl_2$ has the greater degree of covalent character.

(c) $BeCl_2$ has the lower melting point **M1**

(c) $BeCl_2$ has more covalent character, so it exists as discrete molecules/small units held together only by weaker intermolecular forces (e.g. van der Waals forces), oe **B1**

(c) $MgCl_2$ has more ionic character, forming a giant ionic lattice held together throughout by strong electrostatic forces of attraction between oppositely charged ions, requiring more energy to melt, oe **B1**

(c) Answer: $BeCl_2$ has the lower melting point.

Question 5

(a) boiling point increases from F_2 to I_2 **B1**

(a) the number of electrons (and hence the size of the electron cloud) increases as Mr increases down the group, making the molecules more easily polarised, oe **B1**

(a) this gives stronger van der Waals (London/induced dipole-dipole) forces between molecules, so more energy is required to separate them, raising the boiling point, oe **B1**

(a) Answer: Boiling point rises from F_2 to I_2 because increasing numbers of electrons give stronger van der Waals forces.

(b) correct method to find the gradient between the Br_2 and I_2 points: (184-59)/(254-160), oe **M1**

(b) correct use of this gradient to extrapolate from I_2 (Mr = 254, bp = 184°C) to Mr = 420 **M1**

(b) answer consistent with the student's own extrapolation, e.g. approximately 400-410°C, ecf **A1**

(b) Answer: Approximately 405°C (accept any value consistent with a valid linear extrapolation).

(c) the relationship between boiling point and Mr for the halogens is not perfectly linear (the increase in van der Waals forces per unit increase in Mr is not constant), so extending a straight-line trend beyond the measured data may not be accurate, oe **B1**

(c) astatine is extremely rare and highly radioactive, so only minute quantities have ever been studied, meaning there is little reliable experimental data to confirm the trend continues, oe **B1**

(c) Answer: Extrapolation beyond the data assumes an unproven linear trend, and At2 data are extremely scarce.

© Revision Library | revisionlibrary.co.uk