Secondary 6 - Chemistry

Structure, Bonding and the Atom

Name: ______________________________

Class: ______________________________

1. Element X has exactly three isotopes, whose relative isotopic masses are numerically equal to their mass numbers. The relative atomic mass of X is 24.32.

Isotope	Percentage abundance
$^{24}\mathrm{X}$	unknown
$^{25}\mathrm{X}$	10.0%
$^{26}\mathrm{X}$	unknown

What is the percentage abundance of $^{24}\mathrm{X}$?

A. 79.0%

B. 84.0%

C. 11.0%

D. 90.0%

2. A particle contains 16 protons, 18 neutrons and 18 electrons.
Which of the following statements about this particle is / are correct?
(1) It is the $^{34}\mathrm{S}^{2-}$ ion.
(2) It has the same electronic arrangement as a Ca^{2+} ion.
(3) It contains more electrons than neutrons.

A. (1) only

B. (1) and (2) only

C. (2) and (3) only

D. (1), (2) and (3)

3. Sodium chloride melts at $801\,^{\circ}\mathrm{C}$ while caesium chloride melts at $645\,^{\circ}\mathrm{C}$. Both are giant ionic substances.
Which of the following best explains the difference in melting point?

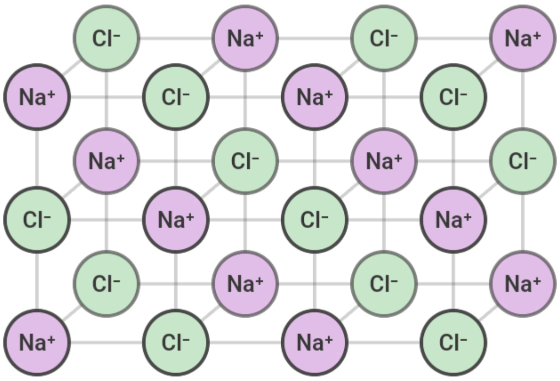
A. The smaller Na^{+} ion allows the oppositely charged ions to come closer, giving stronger electrostatic attraction in the lattice.

B. Sodium chloride is held together by covalent bonds, whereas caesium chloride is held together only by ionic attraction.

C. Each ion in caesium chloride is surrounded by more oppositely charged ions, so the lattice is easier to break apart.

D. The Na^{+} ion carries a higher charge than the Cs^{+} ion, so the ionic bonds in sodium chloride are stronger.

4. The diagram below shows part of the giant ionic structure of sodium chloride.



When a sodium chloride crystal is struck hard, one layer of ions is displaced by exactly one ion position and the crystal splits cleanly instead of bending.
Which of the following best explains this behaviour?

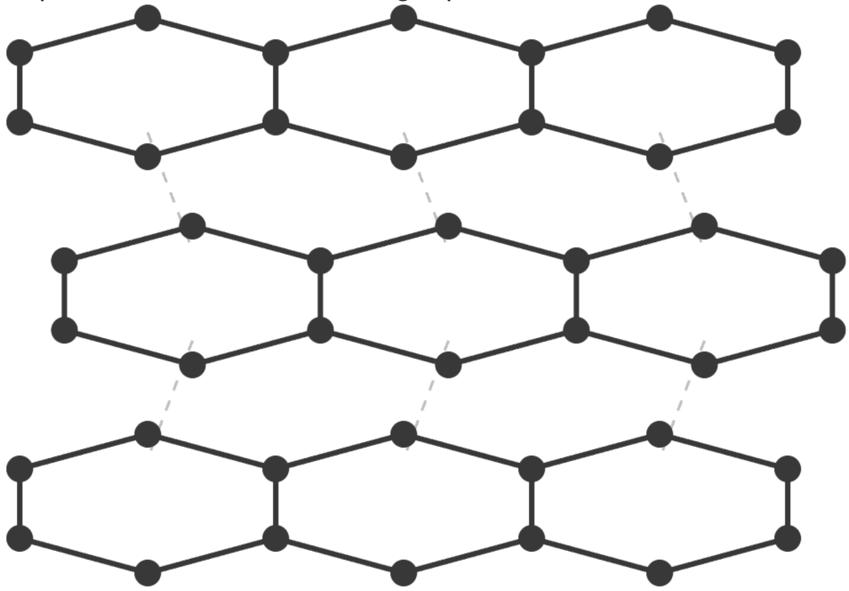
A. Displacement brings ions of the same charge next to each other, and the repulsion between them pushes the layers apart.

B. The weak van der Waals' forces holding the layers together are easily overcome when a force is applied.

C. The ions gain enough energy to become mobile, so the crystal loses its regular shape.

D. The covalent bonds between sodium and chlorine atoms are directional and snap when the layers move.

5. The diagram shows part of the structure of graphite.



A block of graphite conducts electricity well in a direction parallel to its layers, but conducts very poorly in a direction perpendicular to the layers.
Which of the following best explains this observation?

A. Each carbon atom contributes one delocalised electron that moves only within its own layer, and the layers are separated by weak van der Waals' forces.

B. Ions inside each layer are free to move sideways, but they cannot cross the gaps between layers.

C. The covalent bonds within a layer are weaker than those between layers, so electrons escape sideways more easily.

D. Each carbon atom forms four covalent bonds within a layer, leaving no electrons available for movement between layers.

6. Which of the following statements about diamond and graphite is / are correct?
(1) Both substances have very high melting points because strong covalent bonds must be broken before melting.
(2) Graphite is softer than diamond because the covalent bonds within a graphite layer are weaker than the covalent bonds in diamond.
(3) Both substances are insoluble in water and in organic solvents such as hexane.

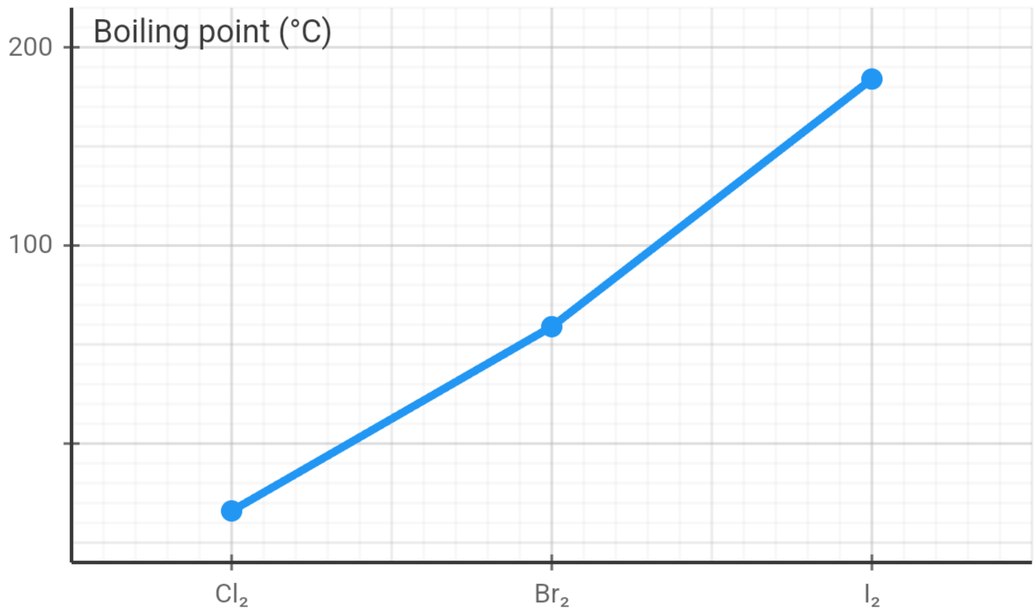
A. (1) and (2) only

B. (1) and (3) only

C. (2) and (3) only

D. (1), (2) and (3)

7. The graph below shows the boiling points of three halogens at standard pressure. Each of them exists as simple diatomic molecules.



Which of the following best explains the trend shown?

A. The molecules become larger with more electrons, so the van der Waals' forces between molecules become stronger.

B. The covalent bond within each molecule becomes stronger, so more energy is needed to boil the substance.

C. The molecules change from a simple molecular structure to a giant covalent structure down the group.

D. The atoms have more occupied electron shells, so the molecules become more chemically reactive on heating.

8. At atmospheric pressure, solid carbon dioxide (dry ice) sublimes at about $-78\,^{\circ}\mathrm{C}$ without melting.
Which of the following statements about dry ice is correct?

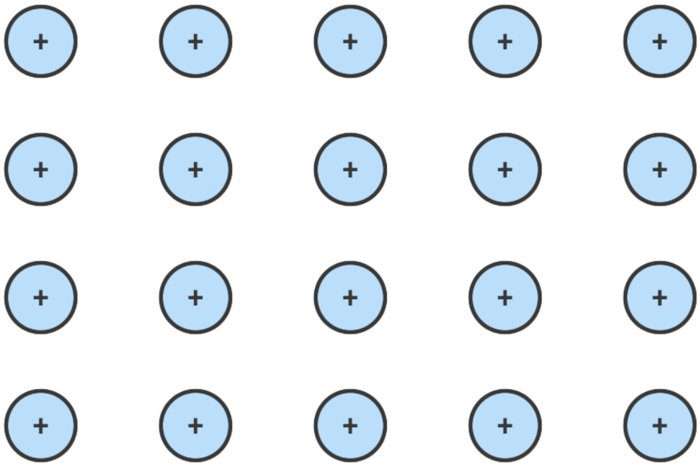
A. On subliming, only the weak van der Waals' forces between the molecules are overcome.

B. On subliming, the double covalent bonds between carbon and oxygen atoms are broken.

C. The low sublimation temperature shows that the carbon-oxygen bonds in the molecule are weak.

D. Dry ice conducts electricity because the delocalised electrons of the oxygen atoms can move.

9. The diagram shows a simple model of the arrangement of particles in a piece of aluminium.



When hammered, a block of aluminium is beaten into a thin sheet, whereas a crystal of an ionic solid of similar hardness shatters.
Which of the following best explains why aluminium can be hammered into a sheet?

A. Layers of positive ions can slide to new positions while the mobile delocalised electrons continue to bind them, so the bonding is re-established rather than destroyed.

B. The metal ions are held together by weak van der Waals' forces, so the layers separate easily when struck.

C. Hammering breaks the directional covalent bonds between the metal atoms, allowing the atoms to be rearranged.

D. The delocalised electrons are pushed out of the metal by the force, so the layers can move apart freely.

10. Sodium melts at $98\,^{\circ}\mathrm{C}$ and can be cut easily with a knife, while magnesium melts at $650\,^{\circ}\mathrm{C}$ and is much harder. Both metals have giant metallic structures.
Which of the following best accounts for the difference?

A. Each magnesium atom provides two delocalised electrons and forms a smaller, doubly charged ion, giving stronger attraction between the ions and the electron sea.

B. Magnesium has covalent bonds between its atoms in addition to metallic bonding, while sodium has metallic bonding only.

C. Sodium ions are heavier than magnesium ions, so the sodium lattice is more easily disrupted on heating.

D. Magnesium has more occupied electron shells than sodium, so its delocalised electrons are held closer to the nuclei.

Structure, Bonding and the Atom

Answers

1 **A**

Relative atomic mass is the weighted average of the isotopic masses, using percentage abundances as weights.

Let the abundance of $^{24}\mathrm{X}$ be $x\%$ and that of $^{26}\mathrm{X}$ be $y\%$.

Since all abundances add to 100: $x + y = 100 - 10.0 = 90.0$

Weighted average: $\dfrac{24x + 25(10.0) + 26y}{100} = 24.32$

$$\begin{aligned} 24x + 250 + 26y &= 2432 \\ 24x + 26y &= 2182 \end{aligned}$$

Substituting $y = 90.0 - x$:

$$\begin{aligned} 24x + 26(90.0 - x) &= 2182 \\ 24x + 2340 - 26x &= 2182 \\ -2x &= -158 \\ x &= 79.0 \end{aligned}$$

So $^{24}\mathrm{X}$ makes up 79.0% (and $^{26}\mathrm{X}$ makes up 11.0%).

2 **B**

The identity of a particle is fixed by its proton number, its charge by the difference between protons and electrons, and its mass number by protons plus neutrons.

(1) Correct. 16 protons means the element is sulphur. Mass number $= 16 + 18 = 34$. Charge $= (+16) + (-18) = -2$, so it is $^{34}\mathrm{S}^{2-}$.

(2) Correct. The particle has 18 electrons, arranged $2, 8, 8$. A calcium atom has 20 electrons, so Ca^{2+} also has 18 electrons arranged $2, 8, 8$ – the same arrangement.

(3) Incorrect. There are 18 electrons and 18 neutrons, so the numbers are equal, not greater.

Hence only (1) and (2) are correct.

3 A

In a giant ionic structure, melting requires enough energy to overcome the strong electrostatic attraction between oppositely charged ions throughout the lattice.

The strength of this attraction increases when the ionic charges are larger and when the ions are smaller (shorter distance between ion centres).

Both compounds contain singly charged ions (Na^+ or Cs^+ with Cl^-), so the charges are the same. However, Na^+ is much smaller than Cs^+, so in sodium chloride the oppositely charged ions can approach more closely and the attraction is stronger. More energy is therefore needed to melt sodium chloride, giving the higher melting point.

4 A

Look at the arrangement in the diagram: positive and negative ions alternate in every direction, so each ion is surrounded by ions of opposite charge and the lattice is held together by strong electrostatic attraction.

If one layer slides by one ion position, ions of the same charge (for example Na^+ directly beside Na^+) are brought face to face. The attraction across that plane is replaced by strong repulsion between like charges, so the layers are forced apart and the crystal cleaves along that plane.

This is why ionic crystals are hard but brittle: the bonding is strong, yet it cannot survive any sliding of layers.

5 A

In graphite each carbon atom uses only three of its four outermost shell electrons to form covalent bonds within a layer. The fourth electron of every carbon atom becomes delocalised and can move freely within that layer.

Because these mobile electrons can travel along a layer, graphite conducts well parallel to the layers.

Between the layers, however, there are only weak van der Waals' forces and no continuous covalent framework or shared delocalised system linking one layer to the next, so electrons cannot easily pass from layer to layer. Conduction perpendicular to the layers is therefore poor.

6 **B**

Diamond and graphite are both giant covalent forms of carbon, so their properties follow from a network of strong covalent bonds.

(1) Correct. In both structures the atoms are joined by a continuous network of strong covalent bonds. Melting (or sublimation) requires breaking these bonds, so extremely high temperatures are needed.

(2) Incorrect. The softness of graphite is not caused by weak covalent bonds. The covalent bonds inside a graphite layer are in fact very strong; it is the weak van der Waals' forces between layers that let the layers slide over one another.

(3) Correct. Dissolving would require breaking a huge number of strong covalent bonds, and the energy released by any solvent interaction is far too small. Both are therefore insoluble in polar and non-polar solvents.

Hence only (1) and (3) are correct.

7 **A**

All three substances are simple molecular. When they boil, only the van der Waals' forces between molecules are overcome — the covalent bonds inside each molecule stay intact.

Reading the graph, the boiling point rises from about $-34\,^{\circ}\mathrm{C}$ for chlorine, to about $59\,^{\circ}\mathrm{C}$ for bromine, to about $184\,^{\circ}\mathrm{C}$ for iodine, so the intermolecular forces must be getting stronger down the group.

Going from $\mathrm{Cl_2}$ to $\mathrm{Br_2}$ to $\mathrm{I_2}$, the molecules become larger and contain more electrons. The larger electron clouds are more easily distorted, giving stronger van der Waals' attraction, so more heat energy is needed to separate the molecules.

8 **A**

Carbon dioxide is a simple molecular substance: within each $\mathrm{CO_2}$ molecule the atoms are joined by strong double covalent bonds, but separate molecules are held together only by weak van der Waals' forces.

Sublimation is a change of state, not a chemical change, so only the forces between molecules are overcome. Because van der Waals' forces are weak, very little energy is needed and the solid sublimes at a very low temperature.

The strong $\mathrm{C=O}$ covalent bonds remain unbroken, which is why the gas produced is still carbon dioxide.

9 A

A metal consists of a regular lattice of positive metal ions surrounded by a sea of delocalised electrons that belong to the whole structure.

When a force is applied, layers of positive ions slide over one another to new positions. The delocalised electrons are free to move with them, so the metallic bonding is immediately re-established around the ions in their new positions.

Crucially, the bonding is non-directional and every ion in the lattice carries the same (positive) charge is shielded by the electron sea, so sliding never brings mutually repelling like charges into direct contact as it does in an ionic crystal. The metal changes shape instead of shattering, which is what we call malleability.

10 A

The strength of metallic bonding is the electrostatic attraction between the lattice of positive ions and the sea of delocalised electrons. It increases when the ions carry a higher positive charge, when the ions are smaller, and when each atom releases more delocalised electrons.

A sodium atom releases one outermost shell electron to give Na^{+}, whereas a magnesium atom releases two to give Mg^{2+}. So magnesium has a doubly charged ion, a smaller ion, and twice as many delocalised electrons per atom.

The attraction between the ion lattice and the electron sea is therefore much stronger in magnesium, so more energy is needed to melt it and its layers resist being pushed apart, making it harder.