

Ions in a sea of electrons

Chemistry grades 9-10 (GCSE · IGCSE · O Level · Class 9-10) · Worksheet answers

Check your reasoning against these answers. Always name the particles (positive ions and delocalised electrons) and say what the particles do. For composition problems, show the fraction or percentage, the multiplication and the unit.

Level: Chemistry grades 9-10 (GCSE · IGCSE · O Level · Class 9-10) · **Curriculum:** GCSE C2

Problem 1 Metallic bond

1. A metallic bond is the electrostatic attraction between positive metal ions and the sea of delocalised electrons.
2. Positive metal ions and delocalised electrons.
3. The number of electrons equals the positive charge of the ions, so the metal is **neutral (zero overall charge)**.

Problem 2 Properties of metals

1. Conducts electricity, malleable and conducts heat. Brittle is not typical, and most metals have high melting points.
2. Brittle, for example a salt crystal or glass.

Conducts electricity, malleable, conducts heat.

Problem 3 Outer electrons and ions

1. Na^+ , Mg^{2+} and Al^{3+} .
2. Sodium adds 1, magnesium adds 2 and aluminium adds 3.
3. $100 \times 3 = 300$ electrons.

Na^+ 1, Mg^{2+} 2, Al^{3+} 3 electrons; 300 electrons from 100 Al atoms.

Problem 4 Property and use

1. Copper conducts electricity well and can be drawn into wires (ductile).
2. Aluminium conducts heat well.
3. Steel is strong and hard, so it can carry heavy loads.
4. Gold is malleable and ductile, so it can be shaped.

Each use follows from conductivity, strength or malleability.

Problem 5 Reading the diagram

1. A is a positive metal ion.
2. B is a delocalised electron.

3. Electrons are repelled by the negative terminal and drift towards the positive terminal, so the left end is connected to the **negative terminal**.

Problem 6 What is an alloy?

1. An alloy is a mixture of a metal with at least one other element.
2. Bronze: copper and tin.
3. Steel: iron and carbon.

Bronze is copper and tin; steel is iron and carbon.

Problem 7 Melting points of metals

1. Tungsten (3422 °C).
2. Sodium (98 °C).
3. Magnesium melts at 650 °C and aluminium at 660 °C, so both are liquid at 700 °C. Iron and tungsten melt at higher temperatures, so they are solid.

Iron and tungsten are solid at 700 °C.

Problem 8 Why metals are malleable

1. Copper ions are arranged in layers. Under force the layers slide over each other into new positions.
2. The electron sea still surrounds every ion after sliding, so the attraction between ions and electrons continues in every position.

Layers slide while the sea of electrons holds the structure together.

Problem 9 Sodium and aluminium

1. Sodium forms Na^+ and aluminium forms Al^{3+} .
2. Sodium gives 1 electron per atom and aluminium gives 3.
3. Al^{3+} ions have a higher charge and there are more electrons in the sea, so the electrostatic attraction is stronger and more energy is needed to overcome it.

Stronger metallic bonding in aluminium gives it the higher melting point.

Problem 10 Gold in a ring

1. $18 \div 24 \times 8.0 \text{ g} = 0.75 \times 8.0 \text{ g} = 6.0 \text{ g}$.
2. $8.0 - 6.0 = 2.0 \text{ g}$.
3. $9 \div 24 \times 8.0 \text{ g} = 0.375 \times 8.0 \text{ g} = 3.0 \text{ g}$.

6.0 g gold, 2.0 g other metals, 3.0 g in 9-carat.

Problem 11 Lead-free solder

1. $0.7 \div 100 \times 250 \text{ g} = 1.75 \text{ g}$.
2. $250 - 1.75 = 248.25 \text{ g}$, or $99.3 \div 100 \times 250 = 248.25 \text{ g}$.

Copper 1.75 g, tin 248.25 g.

Problem 12 Spot the errors

1. Wrong: the positive ions stay in their layers, and electrons carry the charge.
2. Wrong: the positive ions balance the electrons, so the metal is neutral.
3. Wrong: an alloy is a mixture of a metal with another element, not a compound with oxygen.

Electrons carry charge, the metal is neutral, and alloys are mixtures.

Problem 13 Heat along a spoon

1. The ions near the hot end vibrate more and pass energy to their neighbours. The free electrons also gain kinetic energy, move quickly through the metal and transfer the energy to cooler parts.
2. Wood has no free electrons, so energy is transferred only slowly.

Free electrons carry energy through the metal quickly.

Problem 14 Cables for pylons

1. Copper: $100 \div 8.96 = 11.2$. Aluminium: $61 \div 2.70 = 22.6$.
2. $22.6 \div 11.2 = 2.0$ times.
3. Aluminium carries about twice as much conduction for each gram of metal, so cables are lighter and pylons need less strength.

Aluminium is about 2.0 times better per unit mass.

Problem 15 Drawing copper into wire

1. Layers of copper ions slide past each other as the metal is pulled, and the sea of electrons keeps holding the ions together.
2. Length = volume $\div$ area = $12.0 \div 0.0020 = 6000$ cm.
3. $6000 \div 100 = 60$ m.

6000 cm = 60 m of wire.

Problem 16 Carbon in steel

1. $0.80 \div 100 \times 1500$ kg = 12 kg.
2. $1500 - 12 = 1488$ kg.
3. Carbon atoms are a different size from iron atoms and disturb the regular layers, so the layers cannot slide easily and the metal is harder.

12 kg of carbon and 1488 kg of iron.

Problem 17 Conduction in solids

1. Delocalised electrons are free to move through the metal.

2. In solid sodium chloride the ions are held in fixed positions and there are no free electrons.
3. When the salt melts, the ions can move and carry charge.
4. In the metal electrons carry charge. In molten sodium chloride ions carry charge.

Metal: electrons. Molten salt: ions.

Problem 18 Planning a hardness comparison

1. Brass will be harder, because zinc atoms in the copper lattice disturb the layers and stop them sliding.
2. Press a steel ball into each sample with the same load for the same time and measure the diameter of the dent. A smaller dent means a harder sample. Control the load, time and ball size.
3. Flying metal pieces or pinching could injure; wear goggles and handle the weights carefully.

Prediction: brass is harder; the dent is smaller.

Problem 19 Choosing an aircraft metal

1. $4.0 \div 100 \times 2500 \text{ kg} = 100 \text{ kg}$.
2. Copper atoms are larger than aluminium atoms and disturb the layers, so the layers slide less easily.
3. Steel is much denser than aluminium alloys, so it would make the aircraft heavier and use more fuel.

100 kg of copper; stronger because of larger copper atoms in the layers.

Problem 20 Heating a copper wire

1. At 20 °C: $I = 1.5 \div 1.00 = 1.50 \text{ A}$. At 100 °C: $I = 1.5 \div 1.31 = 1.15 \text{ A}$.
2. $(1.31 - 1.00) \div 1.00 \times 100 = 31 \%$.
3. The ions vibrate more strongly at a higher temperature, so the moving electrons collide with them more often, which makes it harder for the current to flow.

1.50 A and 1.15 A; resistance up by 31 %.