

Orbitals, configurations and ionisation energy patterns

Chemistry grades 11-12 (A Level · IB · Class 11-12) · Worksheet

Name: _____ Date: _____ Class: _____

These problems train you to write electron configurations for atoms and ions, to explain ionisation energy trends and dips, and to use successive ionisation data to identify a group. They also include calculations that link kJ mol^{-1} values to single atoms and photons. The level matches A Level, IB Chemistry SL and CBSE Class 11-12. The first problems are recall, the middle ones need explanations, and the last five are multi-step tasks.

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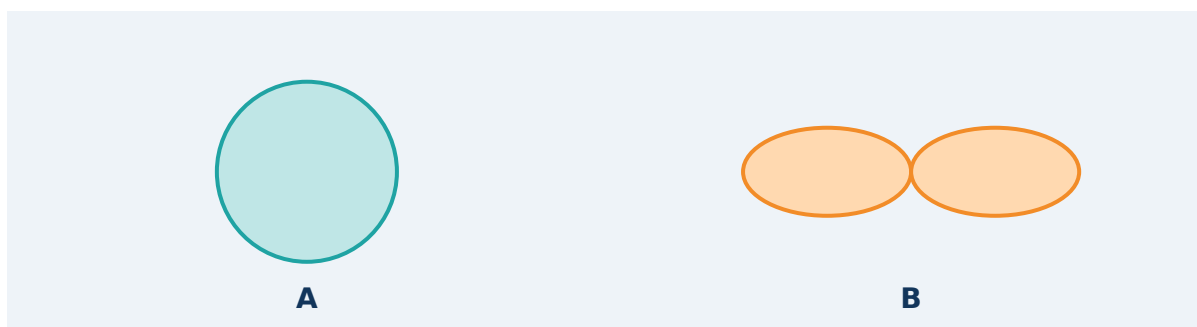
Problem 1 Counting orbitals (easy)

Mei is revising orbitals in Singapore.

1. State how many orbitals are in a p subshell.
2. State the maximum number of electrons in a d subshell.
3. Calculate the maximum number of electrons in the third shell using $2n^2$, and show that it equals the sum over its subshells.

Problem 2 Spot the shapes (easy)

The diagram shows two orbital shapes.



Two orbital shapes, A and B.

1. Name the type of orbital shown by A and by B.
2. State how many orbitals of type B exist in one subshell.
3. Explain why one orbital can never hold three electrons.

Problem 3 Sulfur and chloride (easy)

Write the full ground-state electron configuration of:

1. a sulfur atom (16 electrons)
2. a chloride ion Cl^- (18 electrons)
3. Name the noble gas with the same configuration as Cl^- .

Problem 4 Calcium and its ion (easy)

Calcium has atomic number 20.

1. Write the shorthand configuration of a calcium atom.
2. Write the configuration of Ca^{2+} .
3. State the number of electrons in the outer shell of a calcium atom.

Problem 5 Hund's rule error (easy)

Aarav in Pune draws the 2p electrons of nitrogen as shown.



Aarav's diagram for nitrogen, $2p^6 \dots 2p^3$

Aarav's diagram of the three 2p electrons of nitrogen.

1. Identify the mistake in his diagram.
2. Name the rule that he broke.
3. State how many unpaired electrons a nitrogen atom really has.

Problem 6 Writing the equations (easy)

1. Write the equation that defines the first ionisation energy of sodium, with state symbols.
2. Write the equation for the second ionisation energy of magnesium.
3. State the unit of ionisation energy and explain why its sign is positive.

Problem 7 Energy per atom (medium)

The first ionisation energy of sodium is 496 kJ mol^{-1} . Use the Avogadro constant $6.02 \times 10^{23} \text{ mol}^{-1}$.

1. Calculate the energy needed to ionise one sodium atom, in joules.
2. Calculate the energy needed to ionise 0.250 mol of gaseous sodium atoms, in kJ.

Problem 8 Which block? (medium)

Name the element and the block of the periodic table for each configuration.

1. $[\text{Ne}] 3s^2 3p^3$
2. $[\text{Ar}] 3d^7 4s^2$

3. [Ar] 4s¹
4. 1s² 2s² 2p⁶ 3s² 3p⁶ 3d¹⁰ 4s² 4p⁵

Problem 9 Chromium and copper (medium)

Diego in Texas predicts [Ar] 3d⁴ 4s² for chromium.

1. State the real configuration of chromium (Z = 24) and of copper (Z = 29).
2. Explain why each differs from the simple filling order.
3. Write the configuration of Cr³⁺.

Problem 10 Ions of iron and zinc (medium)

1. Write the configurations of Fe²⁺, Fe³⁺ and Zn²⁺ (Z = 26 and 30).
2. Give the number of unpaired electrons in each ion.
3. Explain why 4s electrons are lost before 3d electrons.

Problem 11 Sodium versus magnesium (medium)

The first ionisation energies are 496 kJ mol⁻¹ for sodium and 738 kJ mol⁻¹ for magnesium.

1. Compare the nuclear charge and the shell of the outer electron in the two atoms.
2. Explain why magnesium has the higher value.

Problem 12 Down group 1 (medium)

First ionisation energies in kJ mol⁻¹: Li 520, Na 496, K 419, Rb 403.

1. Describe the trend.
2. Explain it using distance and shielding.
3. Predict whether caesium is above or below 403 kJ mol⁻¹ and give a reason.

Problem 13 Beryllium to boron (medium)

Beryllium has a first ionisation energy of 900 kJ mol⁻¹ and boron 801 kJ mol⁻¹, although boron has more protons.

1. Write the outer configuration of each atom.
2. Explain why boron is lower.

Problem 14 Nitrogen to oxygen (medium)

First ionisation energies: nitrogen 1402 kJ mol⁻¹, oxygen 1314 kJ mol⁻¹.

1. Draw (describe) the 2p boxes for each atom.
2. Explain why oxygen is lower than nitrogen.

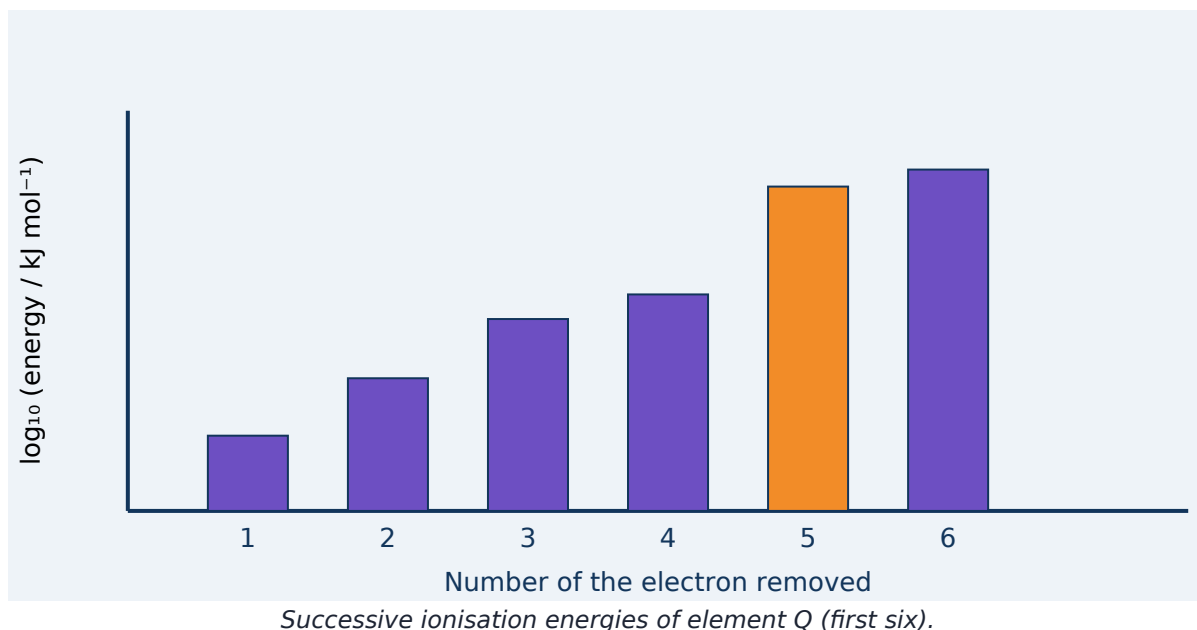
Problem 15 Group from data (medium)

Element X has successive ionisation energies in kJ mol⁻¹: 580, 1820, 2750, 11600, 14800.

1. Identify the number of outer electrons and the group.
2. Write the formula of the chloride of X.
3. Explain why the fourth value is so much larger than the third.

Problem 16 Reading the graph (hard)

The graph shows the first six successive ionisation energies of element Q.



1. Read from the graph the group of Q.
2. Q has 14 electrons in total. Name Q and write its configuration.
3. Predict between which two electrons the next big jump occurs, and explain.

Problem 17 Second ionisation of sodium (hard)

The second ionisation energy is 4562 kJ mol⁻¹ for sodium but 1451 kJ mol⁻¹ for magnesium.

1. Write the configuration of Na⁺ and of Mg⁺.
2. Explain why the second value is so much larger for sodium.

Problem 18 Energy to make Mg²⁺ (hard)

The first and second ionisation energies of magnesium are 738 and 1451 kJ mol⁻¹. Relative atomic mass Mg = 24.3.

1. Calculate the energy to form one mole of gaseous Mg²⁺ ions from gaseous atoms.
2. Calculate the amount of Mg in 3.6 g.
3. Calculate the energy needed to convert 3.6 g of gaseous magnesium atoms into Mg²⁺ ions.

Problem 19 Light that ionises hydrogen (hard)

The ionisation energy of hydrogen is 1312 kJ mol⁻¹. Use $h = 6.626 \times 10^{-34} \text{ J s}$, $c = 3.00 \times 10^8 \text{ m s}^{-1}$.

m/s and $6.022 \times 10^{23} \text{ mol}^{-1}$.

1. Calculate the energy needed to ionise one hydrogen atom, in joules.
2. Calculate the longest wavelength of light that could ionise it, in nm.
3. State which region of the spectrum this is.

Problem 20 Zinc and gallium (hard)

Zinc has a first ionisation energy of 906 kJ mol^{-1} and gallium, one place to the right, has 579 kJ mol^{-1} .

1. Write the outer configurations of both atoms.
2. Explain why gallium is lower even though it has one more proton.