Unit 4 · Classification of Elements

ANSWER KEY · FOR TEACHERS

Full marks 33

Give the marks for the points in the marking scheme; an answer in other words that says the same is right.

1 Key words

1. atomic numbers
2. groups
3. halogens
4. isoelectronic
5. effective nuclear charge
6. ionization energy
7. electronegativity
8. diagonal relationship

K · 4

Each carries 0.5 mark.

2 Label the graph

1. He
2. Ne
3. Na
4. K

U · 2

Each carries 0.5 mark.

3 Multiple choice

i. **b.** atomic number — K · 1

Moseley showed that atomic number, the charge on the nucleus, is what orders the elements: the modern periodic law.

ii. **b.** silicon — K · 1

Silicon lies on the staircase between the metals and the non-metals, with properties of both. Aluminium is a metal; phosphorus and sulphur are non-metals.

iii. **b.** period 3, group 15, p-block — U · 1

Its highest shell is n = 3, so period 3. The last electron enters 3p, so p-block, and it has 2 + 3 = 5 valence electrons: group 10 + 5 = **15**. It is phosphorus.

iv. **d.** O^{2-} — A · 1

All four have 10 electrons. O^{2-} has the fewest protons (8) pulling on them, so its cloud is held least tightly and it is the largest. Mg^{2+} (12 protons) is the smallest.

v. **b.** C–F — A · 1

The bond with the largest difference in electronegativity is the most polar: C–F 1.43, C–O 0.89, C–N 0.49, N–O 0.40.

4 Short answers

a. MARKING SCHEME — U · 2

- ✓ Mg's electron comes from a full, stable 3s subshell.
- ✓ Al's single 3p electron is higher in energy and shielded by $3s^2$, so easier to remove.

b. MARKING SCHEME — U · 2

- ✓ The added electrons go into the inner (n − 1)d subshell.
- ✓ They shield the outer 4s electrons, canceling most of the extra nuclear charge.

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c. MARKING SCHEME A · 3

- ✓ The configuration [Ar] $4s^2\ 3d^{10}\ 4p^5$.
- ✓ Period 4, group 17, p-block.
- ✓ A non-metal (a halogen).

5 Long answer

ANSWER U · 4

Electronegativity is the tendency of an atom in a molecule to attract the shared pair of electrons of a covalent bond towards itself.
It depends on the **size** of the atom and its **effective nuclear charge**: the smaller the atom and the larger *Zeff*, the more strongly the shared pair is pulled.
Across a period it increases: *Zeff* rises and the atoms shrink. **Down a group it decreases**: the atoms get larger and the shared pair is farther from the nucleus.
Na < Mg < Cl < F.

MARKING SCHEME

- ✓ The definition.
- ✓ It depends on atomic size and effective nuclear charge.
- ✓ Increases across a period, decreases down a group, with the reasons.
- ✓ Na < Mg < Cl < F.

6 Numerical problems

a. ANSWER A · 4

i. P: $(1s^2)\ (2s^2\ 2p^6)\ (3s^2\ 3p^3)$. Other electrons in the 3s 3p group: $4 \times 0.35 = 1.40$; shell 2 (n − 1): $8 \times 0.85 = 6.80$; shell 1 (n − 2): $2 \times 1.00 = 2.00$. S = 10.20, so *Zeff* = 15 − 10.20 = **4.80**.

ii. Ca: $(1s^2)\ (2s^2\ 2p^6)\ (3s^2\ 3p^6)\ (4s^2)$. The other 4s electron: 0.35; shell 3: $8 \times 0.85 = 6.80$; shells 1 and 2: $10 \times 1.00 = 10.00$. S = 17.15, so *Zeff* = 20 − 17.15 = **2.85**.

MARKING SCHEME

- ✓ Shielding for P: S = 10.20.
- ✓ *Zeff*(P) = 4.80.
- ✓ Shielding for Ca: S = 17.15.
- ✓ *Zeff*(Ca) = 2.85.

b. ANSWER A · 4

i. Covalent radius = half the distance between the bonded nuclei = 266 ÷ 2 = **133 pm**.

ii. 496 ÷ 96.5 = **5.14 eV** per atom; in joules, 496 000 J ÷ 6.022×10^{23} = **8.24×10^{-19} J** per atom.

iii. C–Cl: ΔEN = 3.16 − 2.55 = 0.61, **polar covalent**. Na–Cl: ΔEN = 3.16 − 0.93 = 2.23, above about 1.7, **ionic**.

MARKING SCHEME

- ✓ 133 pm.
- ✓ 5.14 eV.
- ✓ 8.24×10^{-19} J.
- ✓ C–Cl polar covalent (0.61), Na–Cl ionic (2.23).

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7 Think

ANSWER HA · 3

Fluorine is very small: its seven 2p electrons are crowded close together, so an incoming electron is **repelled** strongly by them, and less energy is released. Chlorine's 3p shell is larger, with more room, so the added electron is repelled less and more energy is released.
Electronegativity is about pulling a **shared pair in a bond**, where fluorine's small size and high effective nuclear charge win; electron affinity is about a **free gaseous atom** taking a whole extra electron. They are different properties, so both statements can be true.

MARKING SCHEME

- ✓ Fluorine is small, and its crowded 2p electrons repel an incoming electron.
- ✓ Chlorine's larger 3p shell has more room, so more energy is released.
- ✓ Electronegativity (a shared pair in a bond) and electron affinity (a free atom gaining an electron) are different properties.

8 Activity: The elements at home

(not marked)

WHAT STUDENTS SHOULD FIND

For example: aluminium foil, Al, metal, group 13, period 3; copper wire, Cu, metal, group 11, period 4; pencil "lead" (graphite), C, non-metal, group 14, period 2; iron nail, Fe, metal, group 8, period 4; zinc coating, Zn, metal, group 12, period 4; table salt's Na (metal, group 1, period 3) and Cl (non-metal, group 17, period 3). Most things around us that are a single element are **metals**, on the left and in the middle of the table: over three-quarters of the elements are metals, and they are strong, shiny and conduct, which is why we make things from them.

Marks by level	Knowledge	Understanding	Application	Higher ability	Total
Marks	6	11	13	3	**33**

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