Unit 6 · Periodic Table

ANSWER KEY · FOR TEACHERS

Full marks 45

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

1 Key words

K · 4

1. atomic numbers
2. periods
3. ionization potential
4. electron affinity
5. electronegativity
6. Hund's rule
7. d subshell
8. inner transition elements

Each carries 0.5 mark.

2 Multiple choice

i. **c.** Hund's rule — K · 1

Hund's rule. Aufbau gives the order of the subshells, and Pauli the limit of two electrons, of opposite spin, in an orbital.

ii. **b.** [Ar] $4s^1$ $3d^5$ — U · 1

A half-filled 3d subshell is extra stable, so one electron moves from 4s to 3d: [Ar] $4s^1$ $3d^5$.

iii. **c.** argon has 18 protons and potassium 19 — U · 1

The modern table is ordered by atomic number, the number of protons. Argon's extra neutrons make it heavier, but it has one proton fewer, so it comes first. (Argon has 22 neutrons in its common isotope, potassium 20: more, not fewer.)

iv. **c.** the d block, group 7 — A · 1

Its last electron, by the Aufbau order, goes into 3d, so it is in the d block; 5 d electrons + 2 s electrons = group 7. It is manganese. The $4s^2$ doesn't make it an s-block element: every element after calcium in period 4 has 4s electrons.

v. **b.** the solution turns brown as iodine is set free — A · 1

Chlorine is more reactive than iodine, so it displaces it: $Cl_2 + 2KI \rightarrow 2KCl + I_2$. The iodine colors the solution brown. Potassium chloride is soluble, so no precipitate forms.

3 Label the graph

K · 4

1. He
2. B
3. Li
4. Ne
5. Ar
6. S
7. Na
8. K

Each carries 0.5 mark.

4 Very short answers

a. MARKING SCHEME — K · 1

✓ The properties are periodic functions of the atomic numbers.

b. MARKING SCHEME — A · 1

✓ [Ar] $3d^5$ (both 4s electrons and one 3d electron lost).

c. MARKING SCHEME — U · 1

✓ It catches fire in air at about 30 °C, and water keeps the air away.

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d. MARKING SCHEME A · 1

✓ Na is larger.

5 Short answers

a. MARKING SCHEME U · 2

✓ Magnesium, [Ne] $3s^2$, loses an electron from a filled 3s subshell.

✓ Aluminium's outermost electron is in 3p, higher in energy and shielded by 3s, so it comes off more easily.

b. MARKING SCHEME U · 2

✓ Fluorine is very small, so its crowded 2p subshell strongly repels an incoming electron.

✓ Chlorine's larger 3p subshell repels it less, so more energy is released (349 against 328 kJ/mol).

c. MARKING SCHEME A · 2

✓ Color comes from electrons jumping between d orbitals; Cu^{2+}, [Ar] $3d^9$, has a partly filled d subshell, so it absorbs part of the light.

✓ Zn^{2+}, [Ar] $3d^{10}$, has a full d subshell, so no such jumps are possible and its compounds are white.

d. MARKING SCHEME K · 2

✓ Any one difference, e.g. an isolated atom against an atom in a molecule.

✓ Any second difference, e.g. an energy in kJ/mol against a number with no unit.

6 Long answers

a. ANSWER U · 4

A period begins with a new shell's s subshell and ends when that shell's p subshell is full, and its length is the number of electrons the subshells it fills can hold. Period 1 fills only 1s: 2. Periods 2 and 3 fill ns and np: $2 + 6 = 8$ (3d is too high in energy to fill in period 3). Periods 4 and 5 fill ns, $(n - 1)$d and np: $2 + 10 + 6 = 18$. (Periods 6 and 7 also fill an f subshell: $2 + 14 + 10 + 6 = 32$.)

MARKING SCHEME

✓ A period starts with a new shell's s subshell and ends when that shell's p subshell is full; its length is the number of electrons those subshells hold.

✓ Period 1 fills only 1s: 2 elements.

✓ Periods 2 and 3 fill ns and np: $2 + 6 = 8$ elements.

✓ Periods 4 and 5 fill ns, $(n - 1)$d and np: $2 + 10 + 6 = 18$ elements.

b. ANSWER A · 4

The reactivity of halogens **decreases down the group**: F > Cl > Br > I. They react by gaining an electron, and down the group the atoms are larger, so the incoming electron is attracted less strongly (electronegativity falls from 3.98 to 2.66).

Experiment (displacement): add chlorine water to potassium bromide and potassium iodide solutions in two test tubes. The first turns orange-yellow (bromine set free), the second brown (iodine set free):

$$Cl_2 + 2KBr \rightarrow 2KCl + Br_2 \qquad Cl_2 + 2KI \rightarrow 2KCl + I_2$$

Bromine water added to potassium iodide also sets iodine free, $Br_2 + 2KI \rightarrow 2KBr + I_2$, but iodine added to potassium chloride or bromide does nothing. So Cl > Br > I.

MARKING SCHEME

✓ Reactivity decreases down the group, F > Cl > Br > I, because the larger atoms attract an incoming electron less strongly.

✓ Chlorine water added to KBr solution turns it orange and to KI solution turns it brown.

✓ $Cl_2 + 2KBr \rightarrow 2KCl + Br_2$ and $Cl_2 + 2KI \rightarrow 2KCl + I_2$.

✓ Bromine sets iodine free from KI, but iodine does nothing to KCl or KBr, so Cl > Br > I.

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7 Numerical problems

a. **ANSWER** A · 3

i. The first three energies rise steadily; the fourth jumps more than four times, because the fourth electron must come out of a full inner shell. So Y has **3 valence electrons**.

ii. **Group 13** (it is aluminium, [Ne] $3s^2\ 3p^1$).

iii. Valency 3 against oxygen's 2: $\mathbf{Y_2O_3}$.

MARKING SCHEME

✓ The big jump comes after the third electron, so Y has 3 valence electrons.

✓ It is in group 13.

✓ Its oxide is Y_2O_3.

b. **ANSWER** A · 2

Moles of Cl atoms $= \frac{3.55}{35.5} = 0.1$ mol.

Energy released $= 0.1 \times 349 =$ **34.9 kJ**.

MARKING SCHEME

✓ Moles of Cl atoms $= 3.55 \div 35.5 = 0.1$ mol.

✓ Energy released $= 0.1 \times 349 = 34.9$ kJ.

c. **ANSWER** A · 4

i. P: [Ne] $3s^2\ 3p^3$, three 3p electrons one to an orbital: **3**.

ii. Fe: [Ar] $4s^2\ 3d^6$, 3d is ↑↓ ↑ ↑ ↑ ↑: **4**.

iii. Fe^{3+}: [Ar] $3d^5$, one in each 3d orbital: **5**.

iv. Cr: [Ar] $4s^1\ 3d^5$, five in 3d and one in 4s: **6**.

The more unpaired electrons, the more strongly paramagnetic a substance is, so of these, **chromium atoms** (6) would be pulled most strongly, then Fe^{3+}. (Iron metal itself is far more magnetic than any of these, because it is ferromagnetic: its atoms' magnets line up together in domains.)

MARKING SCHEME

✓ P, [Ne] $3s^2\ 3p^3$: 3 unpaired; Fe, [Ar] $4s^2\ 3d^6$: 4 unpaired.

✓ Fe^{3+}, [Ar] $3d^5$: 5 unpaired (it loses its 4s electrons first).

✓ Cr, [Ar] $4s^1\ 3d^5$: 6 unpaired.

✓ Chromium atoms are pulled most strongly: the more unpaired electrons, the more strongly paramagnetic.

8 Think

ANSWER HA · 3

More particles don't make an atom bigger; the size of an atom is set by how far out its outer shell is. Lithium and fluorine both have two shells (K and L), so their outer electrons are in the same shell. Fluorine's 9 protons pull its L shell, which feels about +7 after the two inner electrons shield it, much more strongly than lithium's 3 protons pull its single L electron, which feels about +1. So the fluorine atom is far **smaller**: its covalent radius is 57 pm, against lithium's 128 pm. Its nucleus is heavier, but the nucleus is tiny; the electrons decide the size.

MARKING SCHEME

✓ Both atoms have two shells, and an atom's size is set by how far out its outer shell is, not by how many particles it has.

✓ Fluorine's outer shell feels a pull of about +7 and lithium's about +1, so fluorine's is drawn in closer.

✓ So fluorine is the smaller: 57 pm against lithium's 128 pm.

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9 Activity: Atoms to scale

(not marked)

WHAT STUDENTS SHOULD FIND

Radii of 128, 57, 166, 102 and 203 pm give circles of radius 2.56, 1.14, 3.32, 2.04 and 4.06 cm. Lithium, sodium and potassium have 2, 3 and 4 shells and a pull of about +1; fluorine and chlorine have 2 and 3 shells and a pull of about +7. So the circles shrink across a period (Li to F, Na to Cl) and grow down a group (Li, Na, K; F, Cl). Potassium is the biggest and fluorine the smallest.

See it at Science Playground

Exhibits and plants at the center, Bhaktapur, that go with this unit. Book a class visit at science-playground.com/booking.

- **The Giant Periodic Table** (exhibit): The elements stand in order of atomic number: elements in one column, a group, behave alike, and each row is a period.

Marks by level	Knowledge	Understanding	Application	Higher ability	Total
Marks	12	11	19	3	**45**

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