1.2.2 Periodic data and structure

Name: _____ Class: _____ Date: _____ **Total: 26 marks**

KEY WORDS ionisation energy • orbital

Objective

Use configurations, graph axes and structure models to interpret periodic data through krypton. Original supplied data and marking guidance; this is not an official paper.

1 Key knowledge and worked examples

■ Read the subshell and the axis

The s, p and d blocks identify the subshell receiving the differentiating electron. K ends in $4s^1$ and is s-block; Sc ends in $3d^14s^2$ and is d-block; As ends in $4p^3$ and is p-block. Helium is s-block by its $1s^2$ configuration although it is placed with the noble gases.

On a linear energy axis, a rise of 100 kJ mol^{-1} has the same vertical distance everywhere. On a $\log_{10}$ axis, equal distances represent equal energy ratios: changing from 3.0 to 3.3 corresponds to a factor of about 2. Use $\log_{10}(E / \text{kJ mol}^{-1})$ so the logarithm refers to the numerical energy in the specified unit. A logarithmic plot preserves the order of values.

Do not explain every periodic property with nuclear charge alone. Melting depends on the particles, bonding and structure; removing one gaseous electron is a different process from melting a solid.

2 Practice

2.1 Classify K, Sc, As and He into s, p or d blocks using the configurations above. Explain why helium's noble-gas column does not make it a p-block element. [4]

2.2 The following supplied first-ionisation energies are rounded to whole kJ mol^{-1}. Plot all 36 against atomic number, once with a linear energy axis and once with a $\log_{10}$ energy axis. Label axes and identify the noble-gas peaks. [6]

Element	Z	E / kJ mol^{-1}	Element	Z	E / kJ mol^{-1}
H	1	1312	K	19	419
He	2	2372	Ca	20	590
Li	3	520	Sc	21	633
Be	4	900	Ti	22	659
B	5	801	V	23	651
C	6	1086	Cr	24	653
N	7	1402	Mn	25	717
O	8	1314	Fe	26	763
F	9	1681	Co	27	760
Ne	10	2081	Ni	28	737
Na	11	496	Cu	29	746
Mg	12	738	Zn	30	906
Al	13	578	Ga	31	579
Si	14	787	Ge	32	762
P	15	1012	As	33	947
S	16	1000	Se	34	941
Cl	17	1251	Br	35	1140
Ar	18	1521	Kr	36	1351

3 Exam-style questions

3.1 Use your graphs to identify three decreases that mark the start of a new occupied outer shell. Explain the general decrease using distance, shielding and nuclear charge. State one advantage of the logarithmic representation. [4]

3.2 Explain why the first-ionisation energy falls from Be to B and from N to O, although nuclear charge increases in each case. Give the relevant outer configurations. [4]

3.3 Classify Li/Be, B/C, $N_2/O_2/F_2$ and Ne by their Period-2 solid structures. Explain why carbon has a much higher melting temperature than nitrogen, and why melting nitrogen does not break its N≡N bonds. [5]

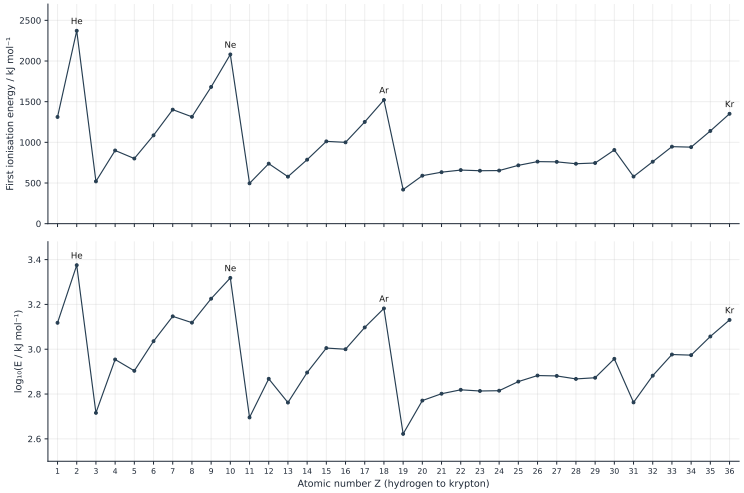
3.4 A student describes the first 36 energies as a smooth rise interrupted only after noble gases. Evaluate this claim using two counterexamples from the table. Explain why this graph alone cannot predict every element's melting temperature. [3]

Solutions

Original authored marking guidance; accept equivalent reasoning and sensible plotting accuracy.

2.1 K s-block, Sc d-block and As p-block. He is s-block because its electrons occupy $1s^2$; the column reflects its full outer shell and chemical behaviour, not a p-electron configuration.

2.2



Linear axes labelled with Z and energy/unit and a consistent scale; all linear points correctly placed. Log axis labelled and scaled, all transformed points correctly placed. He, Ne, Ar and Kr identified as the noble-gas peaks; same ordered data on both plots with no substitution of successive ionisations for different atoms. Accept a correctly labelled logarithmically scaled energy axis.

3.1 He→Li, Ne→Na and Ar→K. The new outer shell puts the electron further from the nucleus with increased shielding; this outweighs the increase in nuclear charge, so less energy removes it. A log axis compresses the large numerical range and makes proportional changes easier to compare.

3.2 Be [He]$2s^2$; B [He]$2s^2 2p^1$: the B electron is removed from the higher-energy 2p subshell, outweighing increased nuclear charge. N [He]$2s^2 2p^3$ has singly occupied p orbitals; O [He]$2s^2 2p^4$ has a first pair, whose repulsion makes one electron easier to remove. No new occupied shell is added in these comparisons.

3.3 Li/Be metallic; B/C giant covalent; N_2/O_2/F_2 simple molecular and Ne monatomic. Carbon melting requires overcoming many strong covalent bonds in its giant structure. Melting nitrogen overcomes attractions between N_2 molecules, retaining the covalent triple bonds inside each molecule. The diagram of a molecule does not imply a giant covalent lattice.

3.4 Valid internal decreases include Be→B, N→O, Mg→Al, P→S, Ti→V, Fe→Co, Co→Ni, Zn→Ga and As→Se. Melting involves the solid's bonding/structure and attractions between its particles, rather than removal of one electron from gaseous atoms; first ionisation alone does not determine it.