

Bohr-Rutherford diagrams: the method and the first 20 elements

Nucleus in the middle labelled with protons (p+) and neutrons (n0); electrons (e-) as dots on shells holding 2, then 8, then 8 (then 2 for potassium and calcium). Protons = atomic number = electrons in a neutral atom. Neutrons = mass number (rounded atomic mass) - atomic number. Fill from the inside; spread electrons to the four positions before pairing.

Z	Element	Sym	Mass	p+	n0	e-	Shells	Valence	Group
1	Hydrogen	H	1	1	0	1	1	1	1
2	Helium	He	4	2	2	2	2	2 (full)	18
3	Lithium	Li	7	3	4	3	2, 1	1	1
4	Beryllium	Be	9	4	5	4	2, 2	2	2
5	Boron	B	11	5	6	5	2, 3	3	13
6	Carbon	C	12	6	6	6	2, 4	4	14
7	Nitrogen	N	14	7	7	7	2, 5	5	15
8	Oxygen	O	16	8	8	8	2, 6	6	16
9	Fluorine	F	19	9	10	9	2, 7	7	17
10	Neon	Ne	20	10	10	10	2, 8	8 (full)	18
11	Sodium	Na	23	11	12	11	2, 8, 1	1	1
12	Magnesium	Mg	24	12	12	12	2, 8, 2	2	2
13	Aluminium	Al	27	13	14	13	2, 8, 3	3	13
14	Silicon	Si	28	14	14	14	2, 8, 4	4	14
15	Phosphorus	P	31	15	16	15	2, 8, 5	5	15
16	Sulfur	S	32	16	16	16	2, 8, 6	6	16
17	Chlorine	Cl	35	17	18	17	2, 8, 7	7	17
18	Argon	Ar	40	18	22	18	2, 8, 8	8 (full)	18
19	Potassium	K	39	19	20	19	2, 8, 8, 1	1	1
20	Calcium	Ca	40	20	20	20	2, 8, 8, 2	2	2

Mass numbers are the most common isotope's (Cl 35.45 -> 35; Ar 39.95 -> 40). Potassium (39) is lighter than argon (40) yet comes after it: the table is ordered by protons. Valence electrons = group number (groups 1-2) or group minus 10 (groups 13-18); shells = period.

The rules

[] Fill from the inside: 2 before any on the second shell, 8 before any on the third

[] The outer shell is the valence shell; its electrons bond. A full outer shell (He 2, Ne 2,8, Ar 2,8,8) is stable: noble gases

[] The third shell takes 8 and then the fourth starts (K 2,8,8,1; Ca 2,8,8,2), which is why the simple diagram stops at 20; the third shell fills to 18 from scandium on (sub-shell notation in senior chemistry)

From

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Ions, isotopes, Lewis diagrams, the mistakes, and a practice set

Ion	From	Electrons	Shells	Charge
Na ⁺	Na 2,8,1 loses 1	10	2, 8	+1 (11 p ⁺ , 10 e ⁻)
Mg ²⁺	Mg 2,8,2 loses 2	10	2, 8	+2
Al ³⁺	Al 2,8,3 loses 3	10	2, 8	+3
O ²⁻	O 2,6 gains 2	10	2, 8	-2
F ⁻	F 2,7 gains 1	10	2, 8	-1
Cl ⁻	Cl 2,8,7 gains 1	18	2, 8, 8	-1 (17 p ⁺ , 18 e ⁻)
K ⁺	K 2,8,8,1 loses 1	18	2, 8, 8	+1

The nucleus never changes in an ion; only electrons move. Metals (1-3 valence electrons) lose and go positive; non-metals (5-7) gain and go negative. Na⁺ beside Cl⁻ is the picture of an ionic bond.

Isotopes	Nucleus	Electrons
Carbon-12 / carbon-14	6p ⁺ 6n ⁰ / 6p ⁺ 8n ⁰	2, 4 in both
Hydrogen-1 / -2 / -3	1p ⁺ 0n ⁰ / 1n ⁰ / 2n ⁰	1
Chlorine-35 / -37 (3:1 in nature)	17p ⁺ 18n ⁰ / 17p ⁺ 20n ⁰	2, 8, 7; average mass 35.45

Lewis dot diagrams

Symbol + dots for the valence electrons only, one on each side before pairing: Na with 1 dot; Mg 2; C 4 single; N 5 (one pair); O 6 (two pairs); Cl 7 (three pairs and a single); Ne 8. The tool for covalent bonds from Grade 10 and GCSE onward.

Mistakes

- [] Electrons in the nucleus or between circles (they sit on the shell lines)
- [] A new shell started before the inner is full; 9 or 10 on the third shell
- [] Atomic number used as mass number (Na is 11 p⁺ and 12 n⁰); atomic mass not rounded (35.45 -> 35)
- [] Protons changed for an ion; an ion drawn with the neutral atom's shells (Na⁺ has two shells)

Practice

1. Draw phosphorus (Z = 15, mass 31). Valence electrons and group?
2. Neutrons in potassium-39? Shell arrangement?
3. Draw a magnesium atom and a magnesium ion. What changes and what stays the same?
4. Oxygen and sulfur are both in group 16. Use their shells to explain why their ions have the same charge.
5. Carbon-12 and carbon-13: which part of the diagram differs?
6. Why does the 2, 8, 8 shell diagram stop at calcium?

Answers

1. 15p⁺ 16n⁰; 2, 8, 5; 5 valence electrons; group 15.
2. 20; 2, 8, 8, 1.
3. Atom 12p⁺ 12n⁰, 2,8,2; ion 2,8 with charge 2⁺; the nucleus is the same, two electrons and one shell are gone.
4. Both have 6 valence electrons (2,6 and 2,8,6) and gain 2 to fill the shell: both 2⁻.
5. Only the nucleus label: 6n⁰ against 7n⁰.
6. From scandium the third shell fills past 8 (to 18) while the fourth already holds electrons; simple shell counting no longer works and sub-shells are needed.