

Ionisation energy

Target level

This is a diagnostic probe designed for post-16 students studying chemistry.

Topics

Ionisation energy, structure of the atom, intra-atomic forces.

Rationale

This probe is designed to elicit common alternative conceptions about the nature of the interactions between an atomic nucleus and electrons. These incorrect ideas tend to be used by students when explaining patterns in ionisation energy. In particular, students commonly consider the nucleus as giving rise to a set amount of force to be shared among electrons (the 'conservation of force' conception). They may also consider that any species with an octet of electrons in the outer shell must be stable.

These ideas are discussed in Chapter 7 of the Teachers' notes.

During piloting, the probe was described as 'demanding' and 'very challenging' (eg 'it does make the students think more than they usually have to about the subject'), but also as 'helpful' and as a 'useful exercise'. It was suggested that the probe is most valuable as a revision exercise at the end of the topic. Some teachers found that the probe led to useful discussions among students, which were 'thought-provoking' and helped to clarify students' ideas.

Instructions

It is worth pointing out to the students that the statements refer to the diagram. You may wish to also remind students that sometimes several factors may influence an effect, and that there may be several ways of explaining the same effect.

If you do not specifically teach the concept of core charge, then you may wish to suggest that students should omit item 10 or you could modify the worksheet.

A blank answer sheet is provided offering the options 'true', 'false' and 'do not know' for each item. An alternative version of the answer sheet only includes the 'true' and 'false' options as some teachers prefer not to allow a 'do not know' option.

Resources

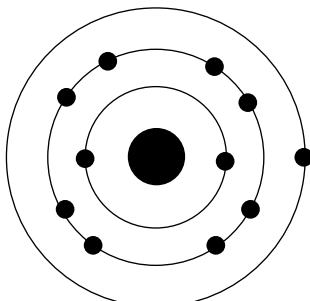
- Student worksheets
 - Ionisation energy – true or false?
 - Ionisation energy – answers

Feedback for students

A suggested answer sheet is provided discussing the science behind the statements.

Ionisation energy – answers

Below you will find listed the 20 items you were asked to think about. Following each is a brief comment suggesting whether or not the statement is true, and why.

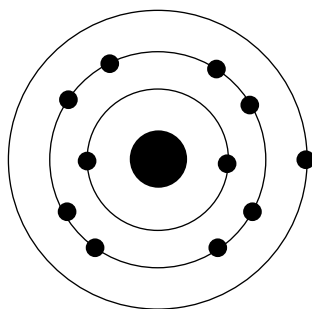


1. Energy is required to remove an electron from the atom.
True: this is the ionisation energy.
2. After the atom is ionised, it then requires more energy to remove a second electron because the second electron is nearer the nucleus.
True: When two charged particles interact the force they experience depends on the size of their charges, and their separation. The greater the separation the smaller the force.
3. The atom will spontaneously lose an electron to become stable.
False: work has to be done to remove an electron – *ie* ionisation energy has to be applied. (This is an endothermic step in the Born-Haber cycle.)
4. Only one electron can be removed from the atom, as it then has a stable electronic configuration.
False: although the second ionisation energy is considerably larger than the first.
5. The nucleus is not attracted to the electrons.
False: The nucleus is attracted to an electron with the same magnitude (size) force as the electron is attracted toward the nucleus.
6. Each proton in the nucleus attracts one electron.
False: All the protons in the nucleus attract all the electrons (and vice versa).
7. After the atom is ionised, it then requires more energy to remove a second electron because the second electron experiences less shielding from the nucleus.
True: For the outermost electron there are 10 shielding electrons (which repel it, and effectively cancel the attraction due to 10 of the 11 protons in the nucleus), so the core charge is +1, but for the next electron removed there are only 2 shielding electrons so the core charge is +9.
8. The nucleus is attracted towards the outermost electron less than it is attracted towards the other electrons.
True: as the nucleus is further from the outermost electron. When two charged particles interact the force they experience depends on the size of their charges, and their separation. The same magnitude (size) force acts on both particles, although the forces are in opposite directions. (The force on the electron is directed toward the nucleus, the force on the nucleus acts towards the electron.)
9. After the atom is ionised, it then requires more energy to remove a second electron because the second electron is in a lower energy level.
True: The outermost electron is a 3s electron, the next to be removed a 2p electron, which is at a lower energy (largely because it is closer to the nucleus, and shielded less and hence attracted more).
10. After the atom is ionised, it then requires more energy to remove a second electron because it experiences a greater core charge than the first.
True: the first electron experiences a core charge of $(11-10)=+1$, the second electron experiences a core charge of $(11-2)=+9$.

11. After the atom is ionised, it then requires more energy to remove a second electron because it would be removed from a positive species.
True: the first electron has to be pulled away from a cation with +1 charge, but the second electron has to be pulled away from a +2 charge, so a greater force has to be overcome.
12. If the outermost electron is removed from the atom it will not return because there will be a stable electronic configuration.
False: unless the electron is attracted somewhere else it will be attracted back to the positive sodium ion.
13. The force on an innermost electron from the nucleus is equal to the force on the nucleus from an innermost electron.
True: the force acting on both has the same magnitude.
14. Electrons do not fall into the nucleus as the force attracting the electrons towards the nucleus is balanced by the force repelling the nucleus from the electrons.
False: as the nucleus is attracted to the electrons, not repelled! The electrons do not fall in to the nucleus as quantum rules only allow the electrons to occupy certain 'positions' *ie* orbitals.
15. The third ionisation energy is greater than the second as there are less electrons in the shell to share the attraction from the nucleus.
False: although the ionisation energy is greater, the attraction from the nucleus is not shared. The actual reasons are (i) there is less repulsion from other electrons counteracting the attraction from the nucleus; and (ii), because of (i), the ionic radius decreases so the third electron (to be removed) is closer to the nucleus.
16. The force pulling the outermost electron towards the nucleus is greater than the force pulling the nucleus towards the outermost electron.
False: Both experience the same magnitude force.
17. After the atom is ionised, it then requires more energy to remove a second electron because once the first electron is removed the remaining electrons receive an extra share of the attraction from the nucleus.
False: more energy is required to remove the second electron as it is closer to the nucleus, experiences a larger core charge, and is being removed from a more positive species. However, the removal of the 3s electron does not increase the attraction to the nucleus experienced by the other electrons.
18. The atom would be more stable if it 'lost' an electron.
False: the separated cation and electron are less stable, which is why energy is required to ionise the atom.
19. The eleven protons in the nucleus give rise to a certain amount of attractive force that is available to be shared between the electrons.
False: the positive charge in the nucleus gives rise a force-field that 'permeates' through space. However there is no force produced unless another charged particle (eg an electron) is present in the field. Each electron will interact with the force field due to the nucleus, without 'using it up' in any way. (The electrons will, of course, repel each other - which may counteract the effect of the attraction towards the nucleus to some extent.)
20. The atom would become stable if it either lost one electron or gained seven electrons.
False: although removal of an electron leaves a stable electronic configuration (2.8, isoelectronic with neon), it requires energy as the isolated (negative) electron and the (positive) cation formed would be attracted back together. Gaining seven electrons would give an octet electronic structure (2.8.8, isoelectronic with argon) – however a seven minus ion (Na^{7-}) would not be stable as the repulsions would far outbalance the attractions. There would be eight electrons in the third shell, all repelling each other, and only attracted to a core charge of +1.

Ionisation energy – true or false?

The statements below refer to this diagram of the electronic structure of an atom.



Please read each statement carefully, and decide whether it is correct or not.

1. Energy is required to remove an electron from the atom.
2. After the atom is ionised, it then requires more energy to remove a second electron because the second electron is nearer the nucleus.
3. The atom will spontaneously lose an electron to become stable.
4. Only one electron can be removed from the atom, as it then has a stable electronic configuration.
5. The nucleus is not attracted to the electrons.
6. Each proton in the nucleus attracts one electron.
7. After the atom is ionised, it then requires more energy to remove a second electron because the second electron experiences less shielding from the nucleus.
8. The nucleus is attracted towards the outermost electron less than it is attracted towards the other electrons.
9. After the atom is ionised, it then requires more energy to remove a second electron because the second electron is in a lower energy level.
10. After the atom is ionised, it then requires more energy to remove a second electron because it experiences a greater core charge than the first.
11. After the atom is ionised, it then requires more energy to remove a second electron because it would be removed from a positive species.
12. If the outermost electron is removed from the atom it will not return because there will be a stable electronic configuration.
13. The force on an innermost electron from the nucleus is equal to the force on the nucleus from an innermost electron.
14. Electrons do not fall into the nucleus as the force attracting the electrons towards the nucleus is balanced by the force repelling the nucleus from the electrons.
15. The third ionisation energy is greater than the second as there are less electrons in the shell to share the attraction from the nucleus.
16. The force pulling the outermost electron towards the nucleus is greater than the force pulling the nucleus towards the outermost electron.
17. After the atom is ionised, it then requires more energy to remove a second electron because once the first electron is removed the remaining electrons receive an extra share of the attraction from the nucleus.
18. The atom would be more stable if it 'lost' an electron.
19. The eleven protons in the nucleus give rise to a certain amount of attractive force that is available to be shared between the electrons.
20. The atom would become stable if it either lost one electron or gained seven electrons.

True or false? – response sheet

1.	True	False	1.
2.	True	False	2.
3.	True	False	3.
4.	True	False	4.
5.	True	False	5.
6.	True	False	6.
7.	True	False	7.
8.	True	False	8.
9.	True	False	9.
10.	True	False	10.
11.	True	False	11.
12.	True	False	12.
13.	True	False	13.
14.	True	False	14.
15.	True	False	15.
16.	True	False	16.
17.	True	False	17.
18.	True	False	18.
19.	True	False	19.
20.	True	False	20.

True or false? – response sheet

1.	True	Do not know	False	1.
2.	True	Do not know	False	2.
3.	True	Do not know	False	3.
4.	True	Do not know	False	4.
5.	True	Do not know	False	5.
6.	True	Do not know	False	6.
7.	True	Do not know	False	7.
8.	True	Do not know	False	8.
9.	True	Do not know	False	9.
10.	True	Do not know	False	10.
11.	True	Do not know	False	11.
12.	True	Do not know	False	12.
13.	True	Do not know	False	13.
14.	True	Do not know	False	14.
15.	True	Do not know	False	15.
16.	True	Do not know	False	16.
17.	True	Do not know	False	17.
18.	True	Do not know	False	18.
19.	True	Do not know	False	19.
20.	True	Do not know	False	20.