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VCE Chemistry ½
Models of the Atoms [1.1]
Homework Solutions

Homework Outline:

Compulsory	Pg 2 – Pg 9
Supplementary	Pg 10 – Pg 20
Solutions	Pg 02 – Pg 20

Section A: Compulsory Questions (45 Marks)

Sub-Section: [1.1.1] Describe the Composition of an Atom, and write the Isotopic Symbol of an Element/Ion & use it to identify an Element's/Ion's Atomic and Mass Number

Question 1 (1 mark)

a. What is the main conclusion that can be made about atoms from Rutherford's Gold Foil Experiment?

Atoms are mostly empty space.

b. Explain how an element can be either an atom or a molecule, giving an example for each case.

An element just needs to be one or more atoms that all have the same atomic number. So one atom of any element is an element such as He, or a molecule that consists of more than one atom, that they all contain the same atomic number, such as O_2 is a molecule and an element.

Question 2 (2 marks)

a. What is the difference between an atom and a molecule?

An atom refers to a single particle with a single nucleus surrounded by electrons, whereas a molecule comprises multiple atoms bonded together.

b. For each of the following, state how many neutrons and electrons each atom has and state what type of molecule it is.

i. $^{27}_{13}Al^{+}$ (1 mark)

13 protons, 12 electrons, 14 neutrons

ii. $^{16}_{8}O^{2-}$ (1 mark)

8 protons, 10 electrons, 8 neutrons

Question 3 (5 marks)

a. Consider Rutherford's model of the atom.

i. Explain the setup of Rutherford's experiment and his subsequent observations. (3 marks)

- Thin gold sheet and shoot alpha particles at it.
- Some reflected back, but most passed through.

ii. Regarding the conclusion, state this conclusion and explain it with reference to the model of an atom. (2 marks)

Atoms are mostly empty space, and we know this because the nucleus itself is the size of a dot in relation to the electron cloud, meaning there is a lot of empty space that exists between the nucleus and the edges of the electron cloud.

b. For Chlorine-35 and Chlorine-37:

i. What are their atomic numbers? (1 mark)

17 for both.

ii. How many neutrons does each atom have? (1 mark)

Chlorine-35: $35 - 17 = 18$ neutrons
Chlorine-37: $37 - 17 = 20$ neutrons

iii. Write out the isotopic symbol for both of them. (1 mark)

$^{35}_{17}\text{Cl}$ and $^{37}_{17}\text{Cl}$

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Sub-Section: [1.1.2] Describe Bohr's Model of the Atom & draw Shell Model diagrams & apply Emission Spectra to Bohr's Model of the Atom

Question 4 (2 marks)

What are two key ideas proposed by Bohr's model of the atom?

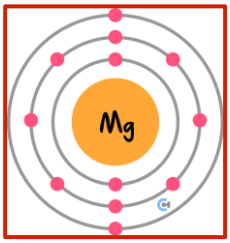
- Electrons can only exist in discrete energy levels, which are regions of space called shells in the electron cloud surrounding the nucleus, and not in between the energy levels.
- Electrons can move between these discrete energy levels.

Question 5 (3 marks)

a. Consider the Rutherford and Bohr models of the atom. Explain the main differences between Bohr's model and Rutherford's model.

Bohr's Model states now that electrons exist at discrete energy levels, whereas Rutherford simply said they existed somewhere random in the electron cloud. Bohr's model also said that the electrons can move through these levels, whereas Rutherford stated it moved randomly.

b. Draw the Bohr shell model diagram for magnesium. (1 mark)



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Question 6 (4 marks)

Consider an atom represented using Bohr's model.

a. When an excited electron exists at $n = 4$, what are all the ways that this electron can fall back to the ground state? (2 marks)

$4 \rightarrow 3 \rightarrow 2 \rightarrow 1$
$4 \rightarrow 3 \rightarrow 1$
$4 \rightarrow 2 \rightarrow 1$
$4 \rightarrow 1$

b. How can we tell the difference between whether the electron has chosen a particular path versus another path, out of the ones that you have described? (2 marks)

Each path has a different energy difference; as such, we can expect the colour of the light that is emitted for each path to be different as well.

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Sub-Section: [1.1.3] Explain Schrodinger's Model of the Atom and identify differences between his Model and Bohr's Model

Question 7 (2 marks)

State all the different orbitals and how many electrons can be held in them.

S, p, d, f and $2, 6, 10, 14$.

Question 8 (3 marks)

What is the difference between Schrödinger's model of the atom and Bohr's model?

Electrons did not orbit the nucleus like planets but had wave-like properties similar to light. Electrons existed somewhere in a region of space that was called an orbital.

Question 9 (1 mark)

Which of the following statements about atomic models is NOT correct?

A. Bohr's model suggests that electrons exist in specific energy levels called shells.

B. Schrödinger's model introduces the concept of orbitals, which describe regions of probability for finding an electron.

C. Bohr's model accurately explains the behaviour of all multi-electron atoms.

D. Schrödinger's model incorporates wave mechanics to describe electron behaviour.

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Sub-Section: [1.1.4] Write Electron Configurations of Elements and Ions, in both Ground and Excited States, using both Bohr and Schrodinger Models (including Cu and Cr exceptions and Condensed Notation)

Question 10 (2 marks)

a. Using Bohr's model, write the electron configuration for magnesium. (1 mark)

2,8,2

b. Now, write the Schrödinger electron configuration for magnesium. (1 mark)

$1s^2 2s^2 2p^6 3s^2$

Question 11 (2 marks)

a. Write the Bohr electron configuration for copper. (1 mark)

2,8,18,1

b. Now, write the Schrödinger electron configuration for copper. (1 mark)

$1s^2 2s^2 2p^6 3s^2 3p^6 4s^1 3d^{10}$

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Question 12 (4 marks)

Consider the element of iron.

a. Write the Schrödinger electron configuration for Iron. (1 mark)

$1s^2 2s^2 2p^6 3s^2 3p^6 4s^2 3d^6$

b. Write its condensed electron configuration. (1 mark)

$[\mathrm{Ar}]4s^2 3d^6$

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Sub-Section: Final Boss

Question 13 (7 marks)

The models of the atom have evolved significantly over time, from Rutherford to Schrödinger. Each model has provided key insights into how atoms behave and their subatomic particles as well.

a. What are some shortcomings of the Bohr model that Schrödinger's model addressed? (3 marks)

- Didn't address why max electrons in each shell is $2n^2$.
- Didn't address why $4s$ is filled before $3d$ subshell.

b. Using Bohr's Model, explain how the emission spectrum of hydrogen is produced and describe how the colour of the emission spectrum is determined. (2 marks)

The emission spectrum of hydrogen is produced when an excited electron dropped backed down to ground state. The energy difference between the levels that the electron jumps determines the energy and wavelength of light, which determines its colour.

c. Write the isotopic symbol for an atom with 17 protons, 20 neutrons, and a charge of -1. (1 mark)

$Z = 17 \rightarrow$ Chlorine, Mass number $= 17 + 20 = 37$, anion

$^{37}_{17}Cl^{-}$

d. Write the Schrödinger electron configuration of the substance you have described in **part a.** (1 mark)

$1s^2 2s^2 2p^6 3s^2 3p^6$

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Section B: Supplementary Questions (63 Marks)

Sub-Section: [1.1.1] Describe the Composition of an Atom, and write the Isotopic Symbol of an Element/Ion & use it to identify an Element's/Ion's Atomic and Mass Number

Question 14 (2 marks)

a. List out the types of subatomic particles that exist. (1 mark)

Protons, electrons, neutrons.

b. State how many protons, neutrons and electrons the following has. (1 mark)

$^{39}_{19}K$

19 protons, 19 electrons, 20 neutrons.

Question 15 (4 marks)

a. Explain why not all molecules are elements, giving an example for each case. (2 marks)

Not all molecules are elements because elements consist of molecules of the same element, which can also be an atom, like N_2, but molecules with different atoms, like H_2O are not considered elements.

b. For each of the following, state how many neutrons and electrons each atom has and state what type of ions it is.

i. $^{24}_{12}Mg^{2+}$ (1 mark)

12 protons, 10 electrons, 12 neutrons; cation.

ii. $^{35}_{17}Cl^{-}$ (1 mark)

17 protons, 18 electrons, 18 neutrons; anion.

Question 16 (3 marks)

a. One student claims that a molecule must always be electrically neutral, but another argues that ions can also form molecules. Who is correct? Justify your answer. (3 marks)

The second student is correct because ions can form molecules in the form of polyatomic ions like SO_4^{2-}.

b. A student argues that the statement that atoms are the smallest possible unit of an element is untrue because of the existence of subatomic particles such as electrons and protons. Evaluate this student's arguments. (3 marks)

The student is incorrect because while atoms may not be the smallest possible unit of matter, atoms are the smallest possible unit of matter that can be classified as elements. A proton inside of a helium atom and a hydrogen atom are identical, but their atoms are different.

Question 17 (7 marks)

Oxygen gas is found in nature not as O by itself but as O_2.

a. Which observation of Rutherford's experiment mainly supported his findings? (2 marks)

The fact that most alpha particles passed through the thin gold sheet.

b. What type of substance do we classify oxygen gas as? (1 mark)

Oxygen gas is described as a molecule but also an element.

c. Suggest a reason as to why oxygen cannot be found naturally as O. (1 mark)

Because it would be unstable by itself.

d. A scientist suggested that to create oxygen in a lab by itself, a potential way to do it would be to take an element that did exist by itself, such as Neon with 10 protons, and then just remove the protons to match the atomic number of oxygen. Explain whether this is possible. (3 marks)

Removing protons from neon would not be possible because the nucleus itself is very stable, and it would be impossibly difficult to change the amount of particles inside of a nucleus. In addition, you would also have to change the number of neutrons and electrons to make it identical to an oxygen atom.

Question 18 (6 marks)

Ions can gain or lose electrons while maintaining the same number of protons. For isotopes, the number of neutrons can differ. Consider the following ions:

$$^{31}_{15}P^{3-} \text{ and } ^{37}_{17}Cl^{-}$$

a. How many neutrons does each have? (1 mark)

For phosphorus ions: $31 - 15 = 16$ neutrons
For chlorine ions: $37 - 17 = 20$ neutrons

b. How many electrons does each have? (1 mark)

Phosphorus ion: $15 + 3 = 18$ electrons
Chlorine ion: $17 + 1 = 18$ electrons

c. Explain whether an ion can also be a molecule or element, providing examples of each case. (2 marks)

An ion can be an element because if it just has one element, it can still be an ion, like Cl^{-}, and also a molecule if it has more than one atom, such as SO_4^{2-}.

d. A student suggests the idea that because atoms are usually neutrally charged, ions will tend to be extremely unstable. Do you agree with the student? Explain your answer. (2 marks)

This is not true because ions can exist naturally and can remain relatively stable because the nucleus (where most of the atom's stability lies) remains intact and only the small electrons are changed.

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Sub-Section: [1.1.2] Describe Bohr's Model of the Atom & draw Shell Model diagrams & apply Emission Spectra to Bohr's Model of the Atom

Question 19 (1 mark)

a. When an electron falls back down to its ground state after being excited, what occurs, and how is it different for each atom?

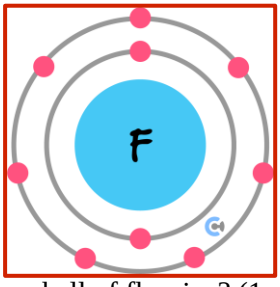
Emission of light, and the colour of light emitted is determined by the difference in energy between the levels of the atom.

b. According to Bohr's model, an electron that moves between $n = 5$ and $n = 2$ emits higher energy light than an electron that falls between $n = 4$ and $n = 2$. Evaluate this statement.

This statement is true because as the shell number increases, the energy difference between $n = 0$ and that shell will also increase because it is further away from the nucleus.

Question 20 (3 marks)

a. Draw the shell model diagram for an atom of fluorine. (1 mark)



b. How many electrons are in the valence shell of fluorine? (1 mark)

7 electrons

c. Explain the Octet Rule. (1 mark)

The valence shell of an atom can hold only eight electrons. All atoms want to fill their valence shell.

Question 21 (2 marks)

a. Explain what happens when an electron is excited past the highest possible shell it can occupy. (1 mark)

It escapes the atom entirely.

b. Suggest a way that we can observe this happening in real life. (1 mark)

Connect the element to a circuit because electrons are responsible for electricity, so we will see current flow (lightbulb circuit).

Question 22 (6 marks)

Consider Bohr's model of the atom and how it explains some parts of an atom's behaviour.

a. State a behaviour of the atom that Bohr's model did not prove. (1 mark)

Did not prove why the $4s$ subshell fills before the $3d$ subshell.

b. What key point of Bohr's model did emission lines on spectra prove? (2 marks)

It proved that electrons existed at discrete energy levels because the emission lines are distinct and specific to each element.

c. What occurs to the energy that exists between the electron shells as we increase the shell number? (1 mark)

It increases.

d. As such, if an atom has $n = 5$, what energy transition would you expect to produce violet light? (2 marks)

Violet = highest energy of light $\rightarrow n = 5$ down to $n = 1$.

Sub-Section: [1.1.3] Explain Schrodinger's Model of the Atom and identify differences between his Model and Bohr's Model

Question 23 (2 marks)

What does the Schrödinger model of the atom say about the position of an electron within an atom?

The Schrödinger model states that electrons are not located in fixed orbits but instead exist in regions of space called orbitals.

Question 24 (3 marks)

Explain the relationship between the principal quantum number, n, the orbital type, and the total number of electrons that can exist in an energy level.

The principal quantum number n represents the energy level of an atom, or simply the number of shells. Each energy level contains orbitals corresponding to: s, p, d or f orbitals, each with different shapes and sizes. The total number of electrons that a shell can hold is $2n^2$, as each orbital holds a maximum of 2 electrons.

Question 25 (1 mark)

Which of the following statements about Schrödinger's model is NOT correct?

A. The exact position of an electron can be calculated using Schrödinger's equation.

B. Orbitals are regions of space where there is a high chance of finding an electron.

C. Schrödinger's model introduced the concept of quantum atomic nature.

D. The Schrödinger model uses math equations to describe electron behaviour.

Question 26 (6 marks)

Consider Schrödinger's model of the atom and the orbitals associated with this model.

a. State the composition of the 3^{rd} shell of an atom. (1 mark)

$1s$ orbital, $3p$ orbitals, and $5d$ orbitals

b. Explain what aspect of Schrödinger's model accounts for the behaviour that the $4s$ subshell is filled before the $3d$ subshell is filled. (3 marks)

Schrödinger's model states that electrons will fill the lower energy subshells to the higher energy ones, and by that logic, this means that the $4s$ subshell has a lower energy than the $3d$, causing the $4s$ subshell to be filled before the $3d$ is filled.

c. Explain why, when we refer to locations of electrons inside of a particular orbital, we use 'somewhere' instead of having an exact location. (2 marks)

Electrons are assumed to be in constant motion, and so their exact location within an orbital is unknown or based off probability.

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Sub-Section: [1.1.4] Write Electron Configurations of Elements and Ions, in both Ground and Excited States, using both Bohr and Schrodinger Models (including Cu and Cr exceptions and Condensed Notation)

Question 27 (1 mark)

Write the Bohr and Schrödinger electron configuration for potassium.

2,8,8,1 and $1s^2 2s^2 2p^6 3s^2 3p^6 4s^1$

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Question 28 (4 marks)

Schrödinger's electron configuration tells us a lot about where the electrons are orientated in an atom.

a. Write the Schrödinger electron configuration for chromium. (1 mark)

$1s^2 2s^2 2p^6 3s^2 3p^6 4s^1 3d^5$

b. Explain why chromium's electron configuration is written in that way instead of being conventional. (2 marks)

This is because half-filled subshells are more stable than partly-filled subshells.

c. Now, write the electron configuration of a chromium in an excited state. (1 mark)

$1s^2 2s^1 2p^6 3s^2 3p^6 4s^2 3d^5$

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Question 29 (6 marks)

The Schrödinger model provides a more comprehensive explanation of an atom's behaviour, focusing on the orbital and subshell concepts. Compared to other models covered, the Schrödinger model is referred to as the most accurate.

a. Explain why the Schrödinger model provides a more accurate representation of the electron arrangement than Bohr's model for elements with more than one electron. (3 marks)

Schrodingers model accounts for the wave like nature of electrons and the probability of their locations, while Bohr's model assumes electrons orbit the nucleus in fixed paths. In multi electron atoms, the interactions between electrons are complex and cannot be accurately described by fixed orbits, making Schrodinger's model more appropriate.

b. Write the Bohr and Schrödinger electron configuration for an atom of titanium. (1 mark)

2,8,8,4
$1s^2 2s^2 2p^6 3s^2 3p^6 4s^2 3d^2$

c. Compare the size of a chlorine atom with the size of a calcium atom. (2 marks)

The calcium atom is larger than the chlorine atom because calcium contains 4 shells whereas chlorine only has 3. We can see this if we write out the configuration as such 2,8,7 (chlorine) vs. 2,8,8,2 (calcium)

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