**Atomic/Molecular Structure A-level Worksheet**

**Hydrogen Spectra and Related**

**1.** **2014. Unit 1. Qn 8b).** The first two electronic energy levels in a hydrogen atom are shown on the diagram.



i) Complete the diagram to show energy levels n=3, n=4 and n=5.

ii) Mark with an arrow the energy change corresponding to the ionisation energy of hydrogen.

**c)** A student said that the ionisation energy of hydrogen could be calculated using the Balmer Series of lines.

i) In which part of the electromagnetic spectrum does the Balmer Series appear?

ii) Explain whether or not this student was correct.

**2.** **2015. Unit 1. Qn 6c.** Explain briefly how the lines in the visible atomic emission spectrum of hydrogen are formed and why the lines become closer together at the high frequency end of the spectrum.

**3.** **2016. Unit 1 (old unit). Qn 7d.** Many fireworks contain metal compounds that emit visible light. The colours given by barium and calcium compound and their wavelengths are given in the table.

|  |  |  |
| --- | --- | --- |
| **Metal** | **Colour** | **Wavelength / nm** |
| Barium | Green | 554 |
| Calcium | Orange-red | 616 |

ii) The colours seen are as a result of the emission of visible light. State how these colours are produced.

**4.** **2016. Unit 1. Qn 12c.** The table shows bond energy values and absorption maxima for the hydrogen halides.

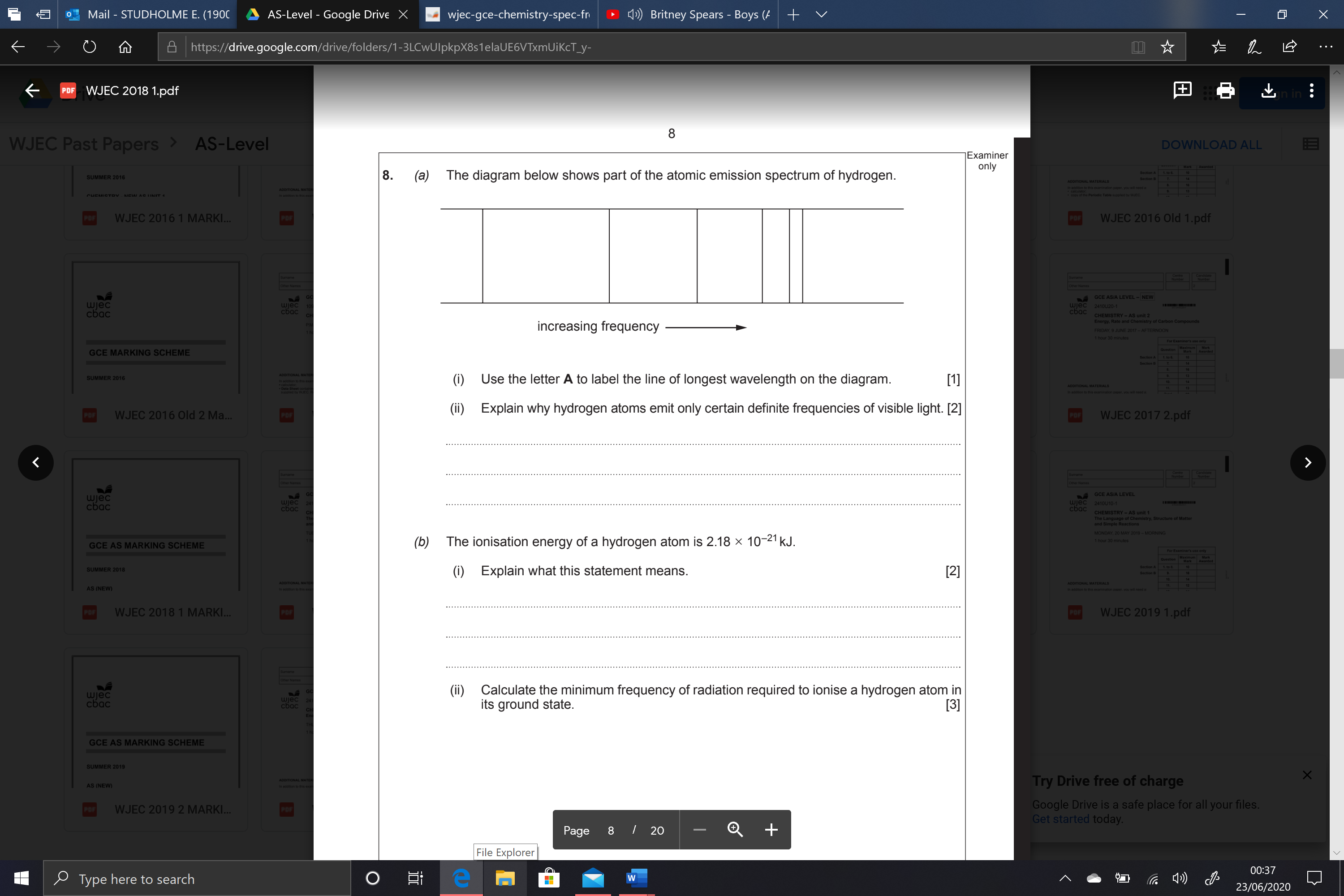
|  |  |  |
| --- | --- | --- |
| **H-X** | **Bond Energy / kJ mol-1** | **Absorption maximum / nm** |
| H-F | 562 | 212 |
| H-Cl | 431 | 278 |
| H-Br | 366 | 326 |
| H-I | 299 | 400 |
| H-At |  |  |

The accepted range for wavelengths for the visible region of the electromagnetic spectrum is 400-700 nm. Suggest and explain why it is probable that H-At would be a coloured gas.

**5.** **2017. Unit 1. Qn 6a.** The atomic spectrum of hydrogen consists of several separate series of lines.

i) In the Balmer series, when an electron returns from the third shell to the second shell, a red line is seen at a wavelength of 656 nm. Calculate the energy of the radiation emitted at this wavelength in Joules.

ii) Explain how the Lyman series can be used to calculate the ionisation energy of hydrogen.

**6.** **2018. Unit 1. Qn 8. a).** The diagram below shows part of the atomic emission spectrum of hydrogen.

i) Use the letter **A** to label the line of longest wavelength on the diagram.

ii) Explain why hydrogen atoms emit only certain definite frequencies of visible light.

**b).** The ionisation energy of a hydrogen atom is 2.18 x 10-21 kJ

ii) Calculate the minimum frequency of radiation required to ionise a hydrogen atom in its ground state in s-1.

**7.** **2019. Unit 1. Qn 10.** When an electrical discharge passes through gaseous hydrogen at low pressure, electromagnetic radiation is emitted.

**a)** Describe the processes within a hydrogen atom that cause electromagnetic radiation to be emitted.

**b)** If the electromagnetic radiation in part **a).** is passed through a spectrometer, several series of converging lines are observed.

i) Explain why there are several series of lines.

ii) Explain why the lines within each series converge.

**c)** The convergence limit of the Lyman series of lines occurs at a wavelength of 91.2 nm.

i) State what the limit represents.

ii) Calculate the energy, in kJ mol-1, of the convergence limit.

**8.** **2014. Unit 4. Qn 4b.** ii) Mandelonitrile is a yellow material. Give the appearance of mandelonitrile when viewed under blue light, giving a reason for your answer.

**9.** **2015. Unit 4. Qn 1a.** Complete the gaps in the following sentence choosing from the words:

Blue Yellow Higher Lower

Each word can be used once, more than once or not at all.

Benzene is a colourless compound that absorbs energy in the ultraviolet region of the electromagnetic spectrum.

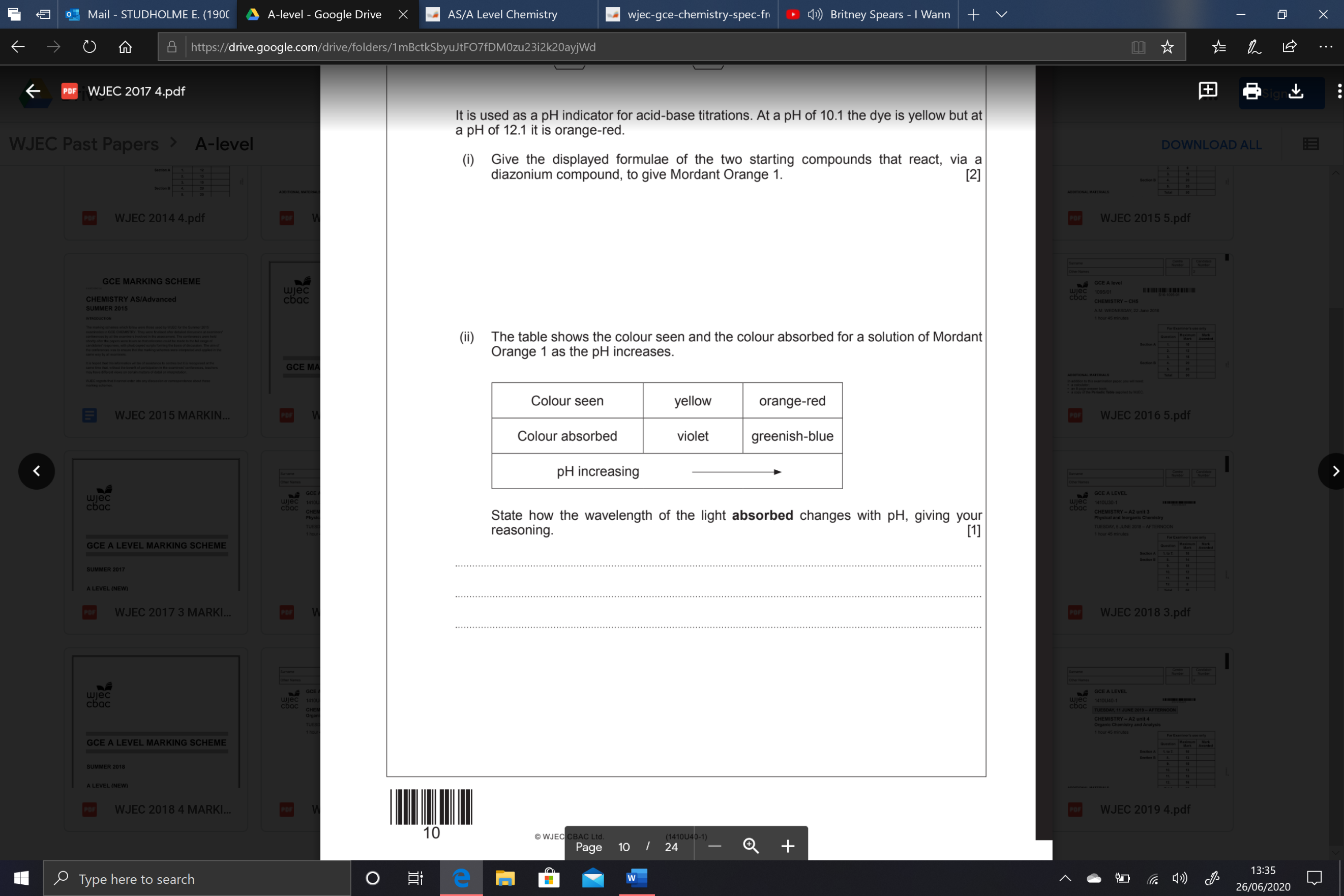
Nitrobenzene is a yellow compound that absorbs energy in the … region of the visible spectrum.

The absorption of energy for benzene occurs at a … energy and at a … frequency than for nitrobenzene.

**10.** **2017. Unit 4. Qn 9a.** ii) DEET is a colourless liquid in white light.

Explain, in terms of the electromagnetic spectrum, why DEET is colourless.

**11.** **2017. Unit 4. Qn 10a.** ii) The table shows the colour seen and the colour absorbed for a solution of Mordant Orange 1 as the pH increases.



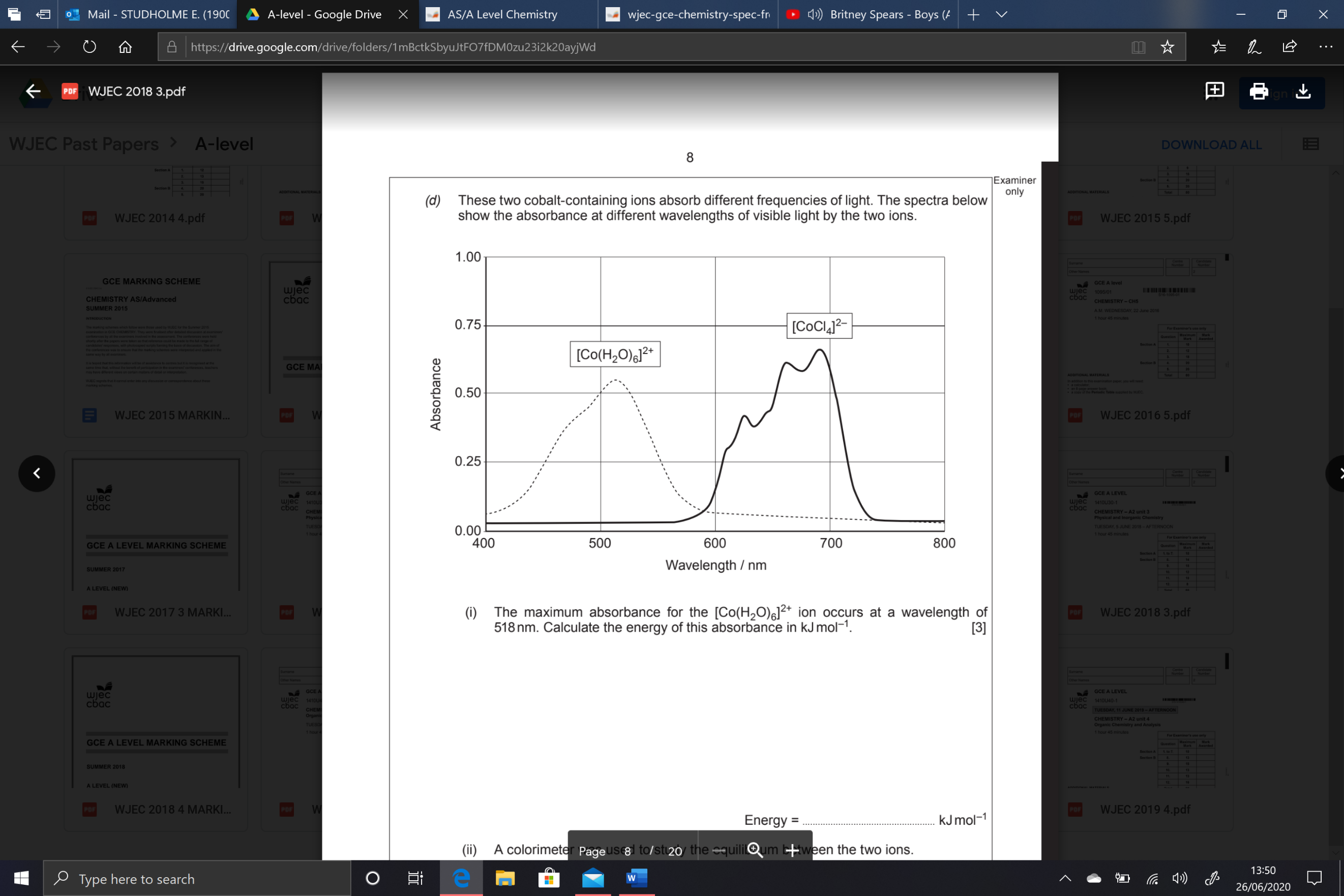
State how the wavelength of the light absorbed changes with pH, giving your reasoning.

iii) The visible spectrum of the dye at pH 10.1 shows it has a maximum absorption at 385 nm.

Calculate the frequency of the radiation being absorbed at 385 nm in Hz.

iv) Use your answer to iii) to calculate the energy of the maximum absorption at 385 nm, giving your answer in kJ mol-1.

**12.** **2018. Unit 3. Qn 9d.** Two cobalt-containing ions absorb different frequencies of light. The spectra below show the absorbance at different wavelengths of visible light by the two ions.



i) The maximum absorbance for the [Co(H2O)6]2+ ion occurs at a wavelength of 518 nm. Calculate the energy of this absorbance in kJ mol-1.

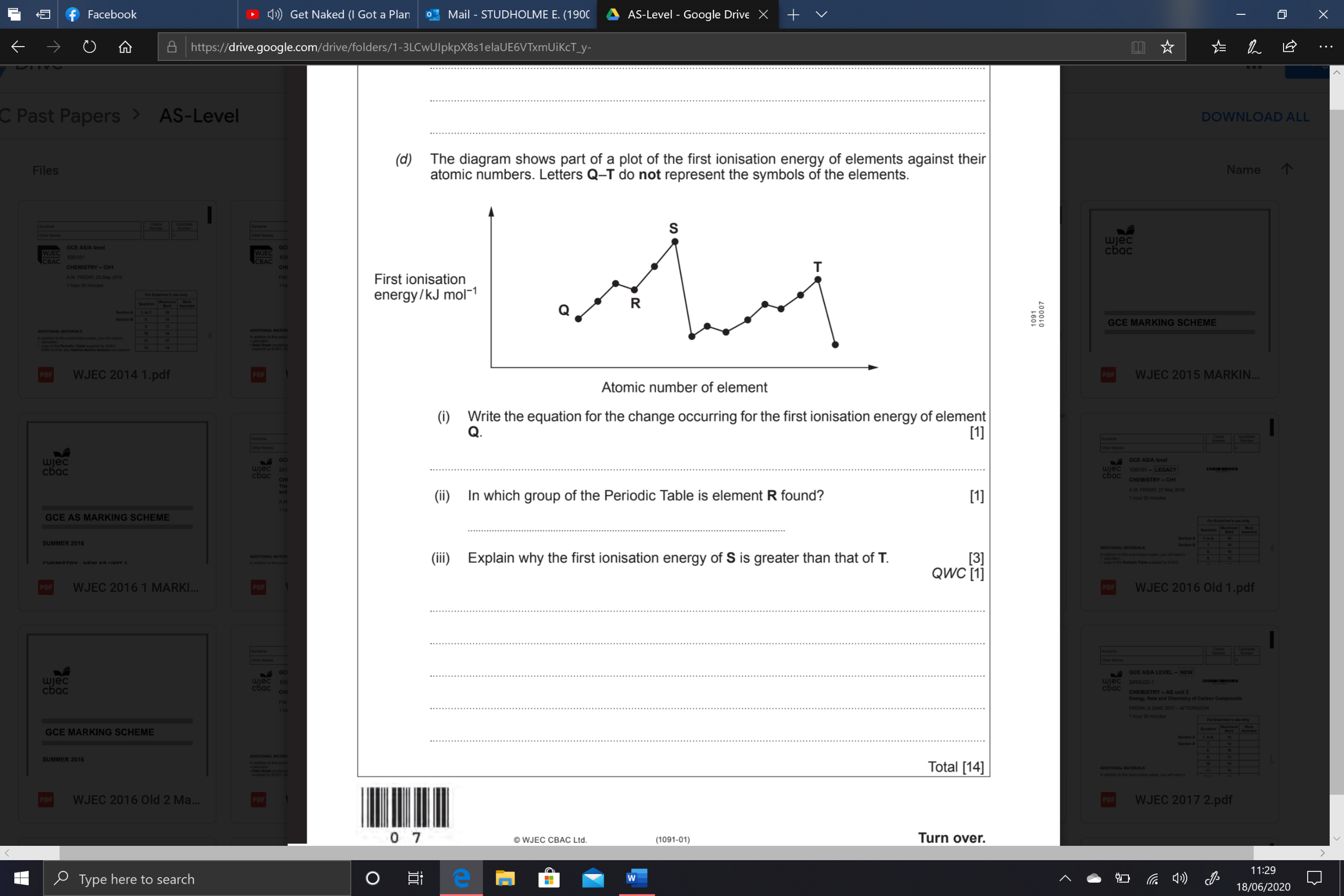
**13.** **2019. Unit 4. Qn 10a.** iii) The visible spectrum of an azo dye at a certain pH shows an absorption maximum at 410 nm. Calculate the frequency that corresponds to this wavelength in Hz.

**Electron Configurations and Ionisation Energies**

**14.** **2014. Unit 1. Qn 1.** Complete the electronic structure of for the sulfide ion present in Na2S.

1s2…

**15.** **2014. Unit 1. Qn 8d.** The diagram shows part of a plot of the first ionisation energy of elements against their atomic numbers. Letters Q-T do not represent the symbols of the elements.

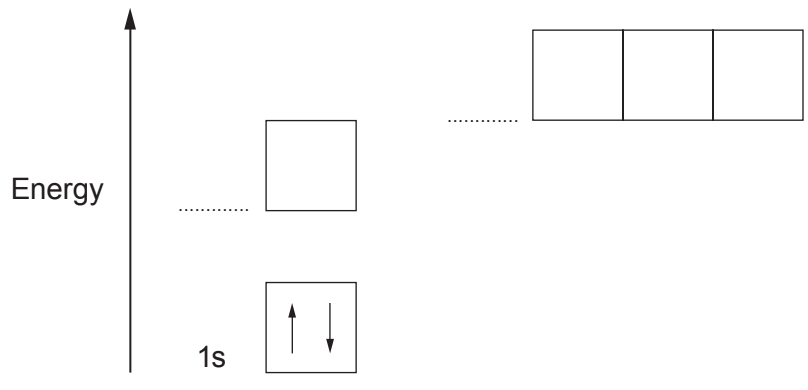


i) Write the equation for the change occurring for the first ionisation energy of element Q.

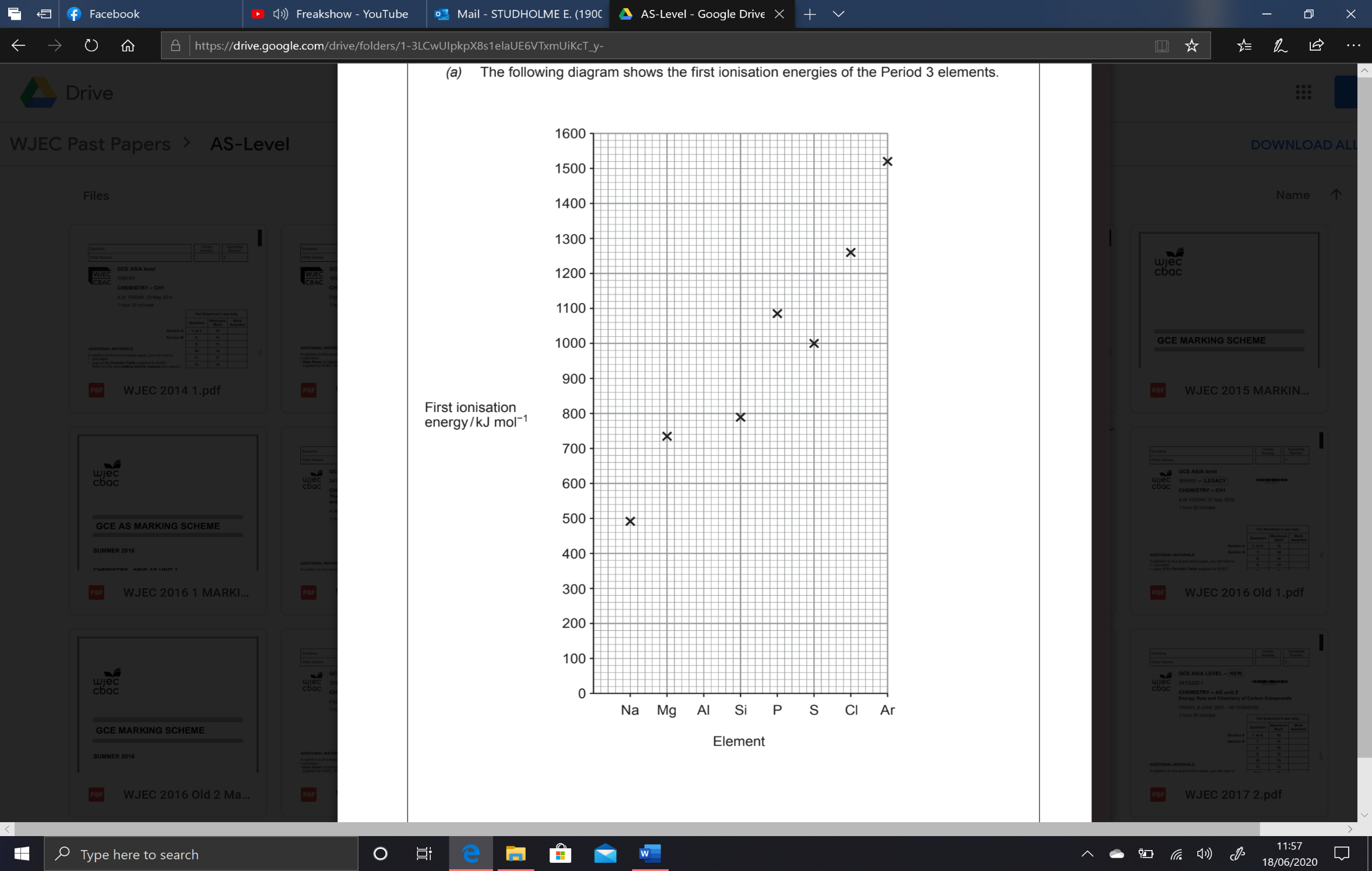
ii) In which group of the periodic table is element R found in?

iii) Explain why the first ionisation energy of S is greater than that of T.

**16.** **2015. Unit 1. Qn 5a.** Electrons are arranged in energy levels. The diagram below shows two electrons in the 1s level in a nitrogen atom. Complete the diagram



**17.** **2015. Unit 1. Qn 6.** Ionisation energies and atomic spectra provide evidence for the arrangement of electrons in atoms.

**a).** The following diagram shows the first ionisation energies of the Period 3 elements.

i) State the meaning of the term *molar first ionisation energy*.

ii) Draw a cross on the diagram to suggest the first ionisation energy of aluminium.

iii) Explain why the value of the first ionisation energy of sulfur is less than that of phosphorus.

**b).** The table below gives some ionisation energies for magnesium.

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
|  | **1st** | **2nd** | **3rd** | **4th** | **5th** |
| **Ionisation Energy / kJ mol-1** | 736 | 1450 |  | 10500 | 13629 |

i) Explain why the second ionisation energy is greater than the first.

ii) Complete the table by suggesting a value for the third ionisation energy of magnesium.

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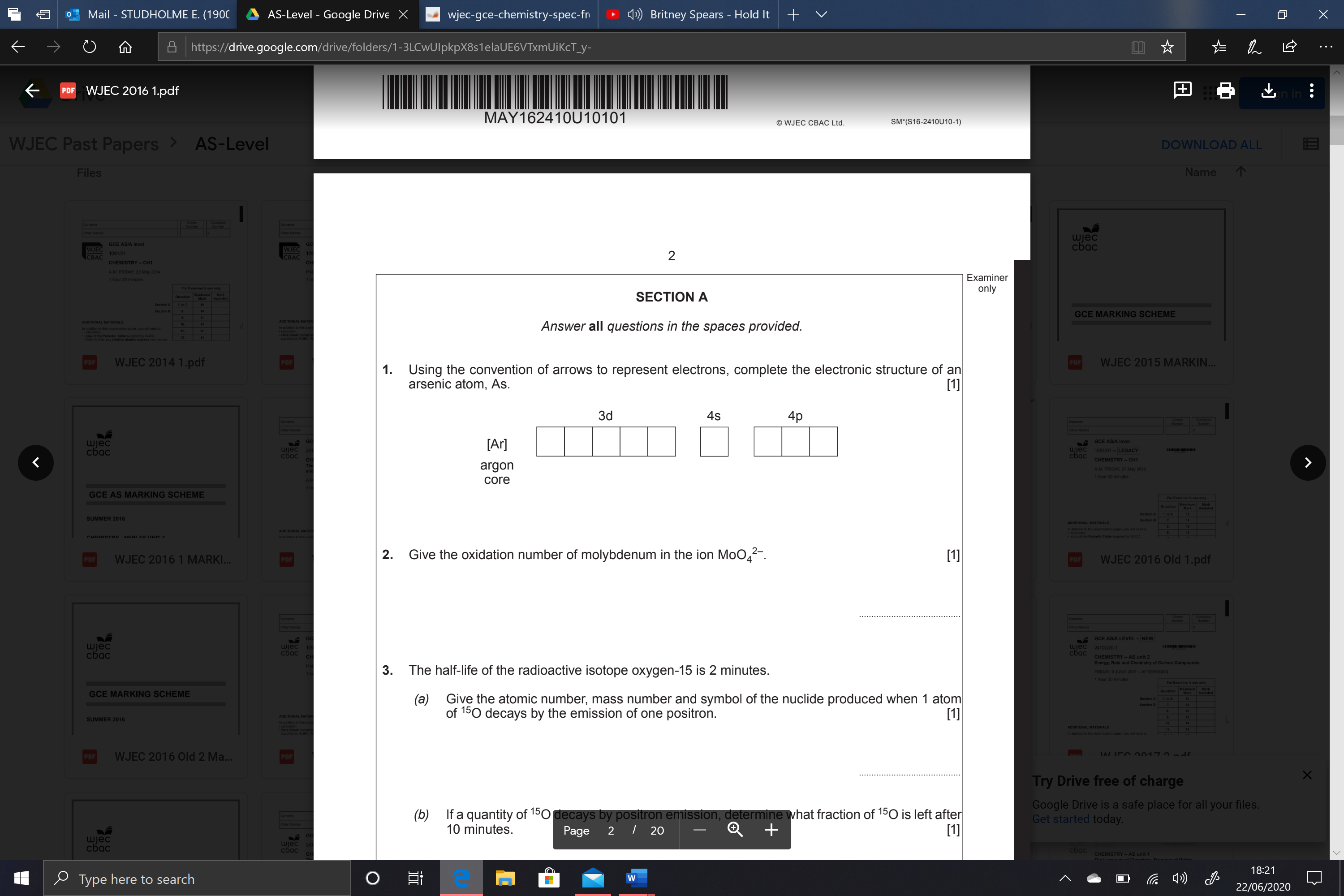
**19.** **2015. Unit 2. Qn 1.** Complete the electronic structure for the oxide ion present in magnesium oxide.

1s2…

**20.** **2015. Unit 2. Qn 9a.**  ii) Describe the trend in the first ionisation energy of Group 1 elements and explain why this trend occurs.

**21.** **2015. Unit 2. Qn 10a.** State why nitrogen is described as a p-block element.

**22.** **2016. Unit 1. Qn 1.** Using the convention of arrows to represent electrons, complete the electronic structure of an arsenic atom, As.

 3d 4s 4p

**23.** **2016. Unit 1 (old unit). Qn 1.** Using the convention of arrows to represent electrons, complete the electronic structure of an atom of chromium.

**↿⇂**

**↿⇂**

**↿⇂**

**↿⇂**

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1s 2s 2p 3s 3p 3d 4s

**24.** **2016. Unit 1 (old unit). Qn 2.**  State which one of the following statements is true.

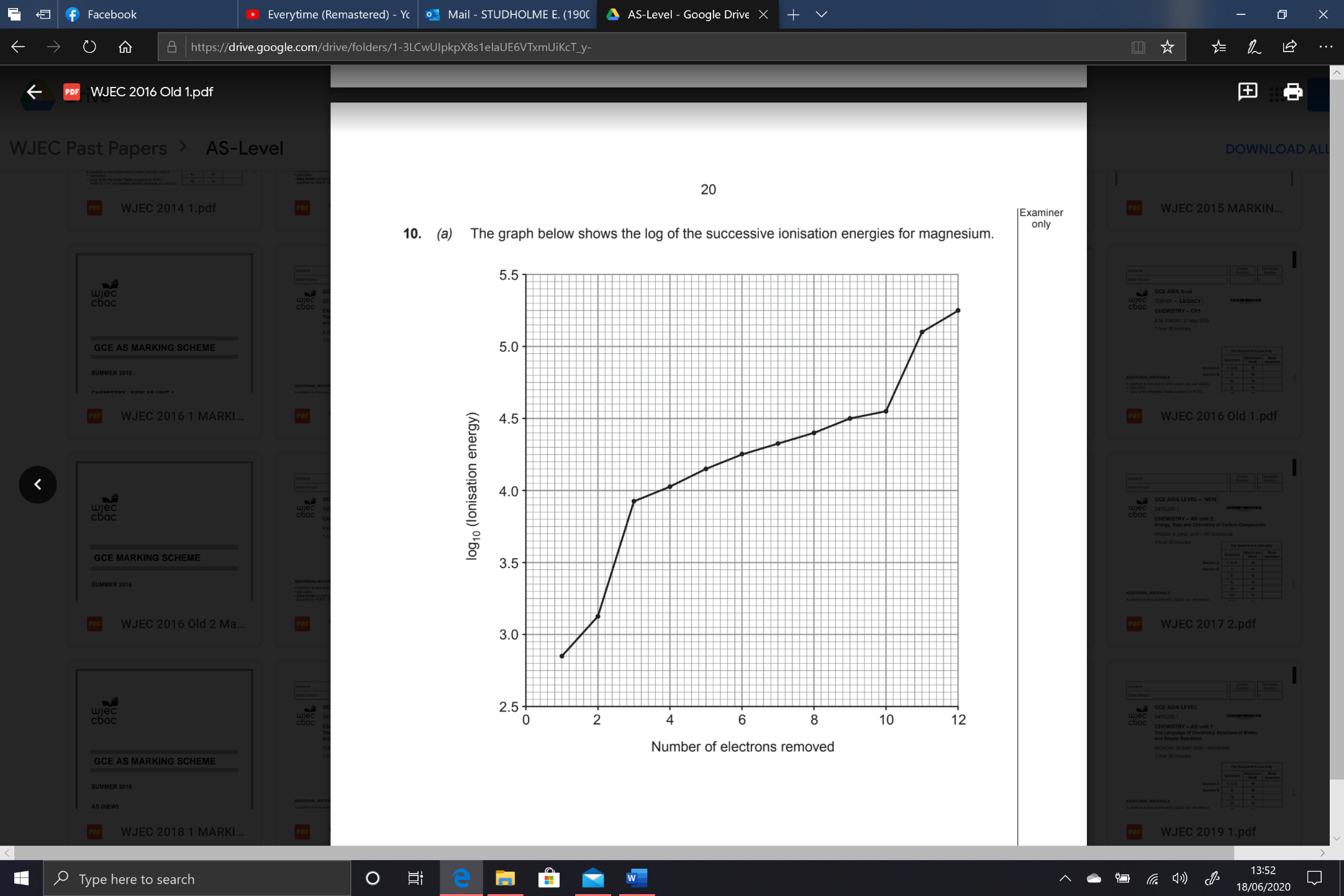
**A.** The first ionisation energy of neon is greater than the first ionisation energy of helium.

**B.** The first ionisation energy of sodium is less than the first ionisation energy of neon.

**C.** The first ionisation energy values increase down Group 1.

**D.** The second ionisation energy of sodium is less than the first ionisation energy of sodium.

**25.** **2016. Unit 1 (old unit). Qn 10a.**  The graph below shows the log of the successive ionisation energies for magnesium.



Using the electron configuration for magnesium, discuss how and why the values for the ionisation energies change according to the number of electrons removed.

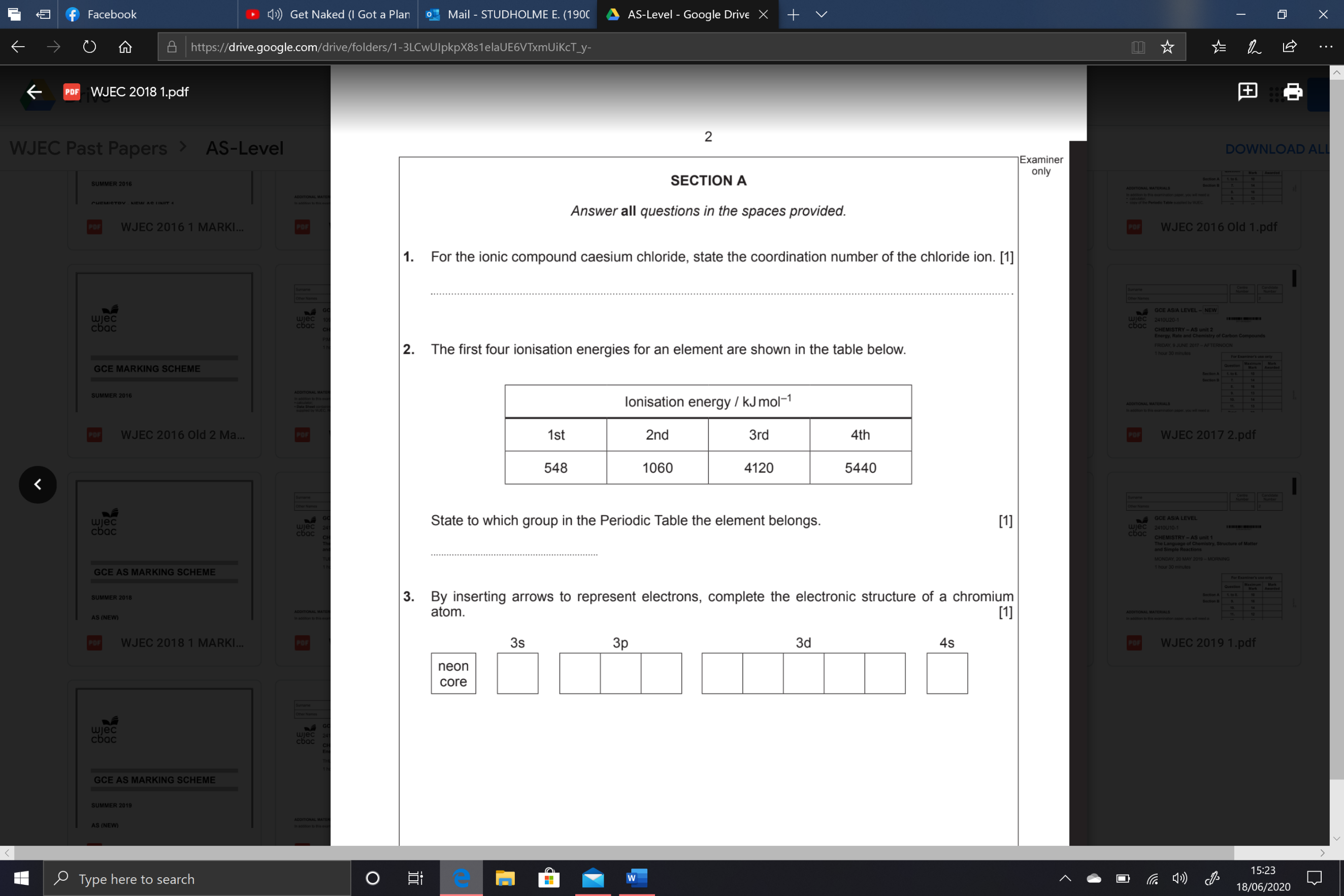
**26.** **2016. Unit 2 (old unit). Qn 4a.**  Place the following elements in order of their increasing first ionisation energies.

Sodium Magnesium Aluminium Silicon Chlorine

**27.** **2017. Unit 1. Qn 6b.** State and explain how you would expect the ionisation energy of hydrogen to compare with the first ionisation energy of:

i) Helium

ii) Lithium

**28.** **2018. Unit 1. Qn 2.** The first four ionisation energies for an element are shown in the table below.

State to which group in the Periodic Table the element belongs.

**29.** **2018. Unit 1. Qn 3.** By inserting arrows to represent electrons, complete the electronic structure of a chromium atom.

3s 3p 3d 4s

Ne

**30.** **2018. Unit 1. Qn 7b.** State and explain how you would expect the first ionisation energy of nitrogen to compare with the first ionisation energy of oxygen.

**31.** **2018. Unit 1. Qn 8bi.** The ionisation energy of a hydrogen atom is

2.18 x 10-21 kJ. Explain what this statement means.

**32.** **2019. Unit 1. Qn 4.** Sodium forms only one stable ion, By inserting arrows to represent electrons, complete the electronic structure of this ion

1s 2s 2p 3s 3p

**↿⇂**

**33.** **2019. Unit 1. Qn 9a.**  Consider the elements labelled **A-G**. These are not chemical symbols.

**A** 1s22s22p1

**B** 1s22s22p3

**C** 1s22s22p6

**D** 1s22s22p63s2

**E** 1s22s22p63s23p1

**F** 1s22s22p63s23p6

**G** 1s22s22p63s23p64s1

i) Give the letter (**A-G**) of the element with the largest first ionisation energy. Give two reasons for your answer.

ii) Give the letter (**A-G**) of the element with the smallest first ionisation energy. Give a reason for your answer.

**34. 2018. Unit 3. Qn 1.** Give the electron configuration of a copper atom.

**35.** **2019. Unit 3. Qn 1.** Complete the electronic configuration of the Co2+ ion below.

1s22s22p63s23p6…

**Lewis Structures and VSEPR**

**36.** **2014. Unit 2. Qn 6.** Select all the molecules from the list below that have bond angles of less than 109°.

**A** NH4+

**B** BF3

**C** NH3

**D** CH4

**E** SF6

**37.** **2015. Unit 2. Qn 10b.** ii) State the bond angle in the ammonium ion. Explain why this is the case.

**38.** **2016. Unit 1. Qn 10b.** Rhiannon studiedthe properties of silicon and found that its structure is similar to that of diamond. In her report she stated that

**.** The Si-Si-Si bond angle is 109.5°

**.** Silicon is a poor conductor of electricity

**.** Each silicon atom is bonded to four other silicon atoms

i) State the name of the shape that has this bond angle.

**39.** **2016. Unit 1. Qn 10d.** i)Hydrofluoric acid will dissolve silica, SiO2, to produce hexafluorosilicic acid. This acid contains the SiF62- ion. Use the information from the table below to draw the shape of the SiF62- ion, showing the F-Si-F bond angle. Give a reason for your answer.

|  |  |  |
| --- | --- | --- |
| **Ion** | **Number of Bonding Electron Pairs** | **Number of Lone Electrons Pairs on the Central Silicon Atom** |
| SiF62- | 6 | 0 |

**40.** **2016. Unit 2 (old unit). Qn 9a.** Modern artificial fertilisers contain many ions that are used by plants to help their growth. These include potassium ions, nitrate ions and phosphate ions.

Ammonium ions are tetrahedral.

ii) State the bond angle in a tetrahedral ion.

iii) State and explain the shape of a molecule of ammonia.

**41.** **2015. Unit 2. Qn 10b.** i) Draw a dot-and-cross diagram to show the electrons in the ammonium ion, NH4+. You should include outer electrons only.

**42.** **2017. Unit 1. Qn 6d.** Hydrogen can form a range of covalent hydrides such as water, H2O, and beryllium hydride, BeH2. A student said that since the ratio of hydrogen to the other element is the same in both compounds, the shapes of the two compounds will be the same. Is she correct? Justify your answer.

**43.** **2019. Unit 1. Qn 13c.** ii) Name the shape of the [ClF6]+ ion.

iii) [ClF2]+ and [ClF2]- are two other ions containing a chlorine atom.

A student said that their shapes must be different.

Is he correct? Justify your answer using VSEPR theory.

**Polarity, Electronegativity and Bonding**

**44.** **2014. Unit 2. Qn 3.** Draw dot-and-cross diagrams to show the formation of calcium chloride from atoms of chlorine and calcium.

**45.** **2018. Unit 1. Qn 5a.** Give the meaning of the term *electronegativity*.

**b).** Explain why electronegativity increases across a period in the Periodic Table.

**46.** **2014. Unit 2. Qn 4.** The table below gives the electronegativity values of some elements.

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| Atom | H | N | O | Al | Cl |
| Electronegativity value | 2.1 | 3.0 | 3.5 | 1.6 | 3.0 |

**a).** Use the data in the table to identify any dipoles present in the following bonds. Mark their polarity clearly.

**N – H O – Cl**

**b).** Use the data to give a reason why aluminium chloride is considered to be a covalent compound, while aluminium oxide is an ionic compound.

**47.** **2014. Unit 2. Qn 9e.** Carbon monoxide contains two covalent bonds and one co-ordinate bond. Explain what is meant by the terms *covalent bond* and *co-ordinate bond*, indicating the difference between them.

**48.** **2017. Unit 1. Qn 3b).** Give one example of a species containing a co-ordinate bond.

**49.** **2015. Unit 2. Qn 9b.** A GCSE student said that, apart from metallic bonding, bonds were either ionic or covalent. An A-Level student said that this was not really true and that bonds could be intermediate between ionic and covalent.

i) State one factor that governs what type of bond elements form and explain how this leads to different types of bonding.

ii) Describe the electron density in each type of bond.

Ionic, covalent and intermediate.

**50.** **2017. Unit 1. Qn 2.** Identify the two elements from the following list that together produce the most ionic bond. Explain your choice.

**Bromine Magnesium Oxygen Sodium**

**51.** **2018. Unit 1. Qn 8d.** i) Draw a dot-and-cross diagram to show the electron arrangement in hydrazine, N2H4. Show outer electrons only.

ii) Hydrazine contains polar covalent bonds between nitrogen and hydrogen atoms. State what is meant by a *polar covalent* bond.

**52.** **2014. Unit 5. Qn 3a.** A molecule of hydrogen peroxide has the molecular formula H2O2. Using outer electrons only, draw a dot-and-cross diagram to show the bonding in a hydrogen peroxide molecule.

**53.** **2017. Unit 4. Qn 10b.** iv) 5-Amino-2-hydroxybenzoic acid can be used in medicine to treat a number of conditions. It is believed to work by removing free radicals. One of these radicals is the hydroxyl radical. This can be produced by the homolytic bond fission of hydrogen peroxide, H2O2, where the O-O bond is broken. Draw a dot and cross diagram of the hydroxyl radical, showing the outer electrons for each atom.

**Solid Structures**

**54.** **2014. Unit 2. Qn 9c.** A different oxide of iron is iron(II) oxide, FeO. The ions in this compound adopt an arrangement similar to that of sodium chloride.

i) Give the crystal co-ordination numbers for the ions in FeO.

ii) Draw the arrangement of oxide ions around each iron ion.

**55.** **2014. Unit 2. Qn 9f.**

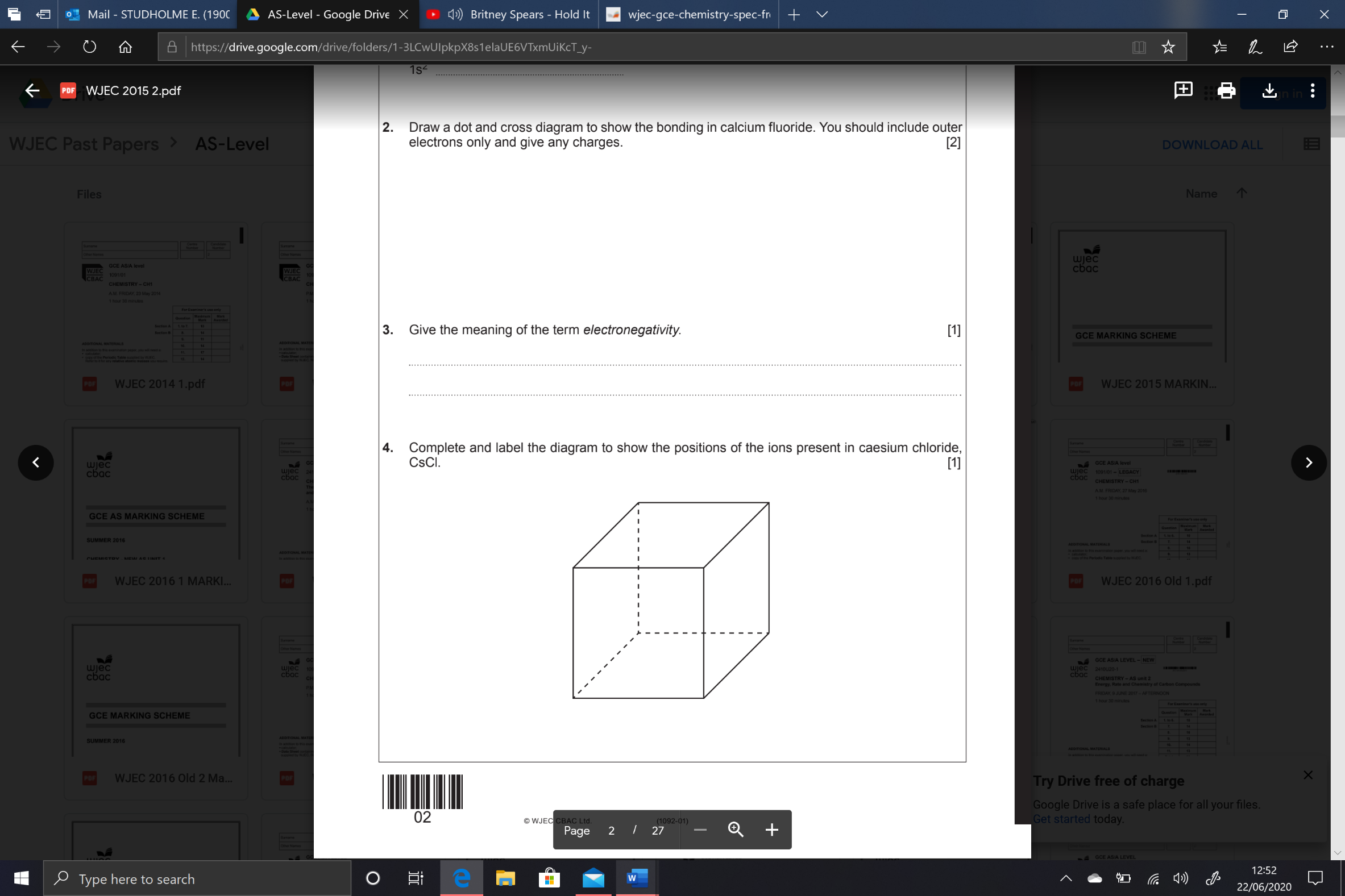
Iron is a typical metal. Describe the bonding present in iron. Explain how it can conduct electricity and why it has a high melting temperature.

**56.** **2015. Unit 2. Qn 12a.** Explain each of the following observations concerning the substances that you have met in your study of Chemistry.

Aluminium has a higher melting temperature than sodium. You should refer to the nature of the bonding.

**57.** **2016. Unit 1. Qn 8c.** Magnesium sulfide has the same crystal structure as sodium chloride.

Use the diagram below to show the crystal structure of magnesium sulfide, clearly labelling the formula of each species present.



**58.** **2016. Unit 1. Qn 10b.** Rhiannon studiedthe properties of silicon and found that its structure is similar to that of diamond. In her report she stated that

**.** The Si-Si-Si bond angle is 109.5°

**.** Silicon is a poor conductor of electricity

**.** Each silicon atom is bonded to four other silicon atoms

ii) Explain why solid silicon is a very poor electrical conductor.

iii) Explain why the bonding between each atom is covalent.

**59.** **2016. Unit 2 (old unit). Qn 4b.** Place the following elements in order of their increasing melting temperature.

**Sodium Magnesium Aluminium Silicon Chlorine**

Lowest…………………………………………………………………………………………………..Highest

**60.** **2016. Unit 2 (old unit). Qn 11a.** i) Draw the arrangement of ions in solid caesium chloride, labelling the diagram clearly.

ii) Explain why the co-ordination numbers of the ions in caesium chloride and sodium chloride are different.

**c)** Sodium chloride and sodium metal can both conduct electricity under different conditions. Give the conditions needed for each to conduct and explain how each conducts electricity.

**61.** **2017. Unit 1. Qn 9e.** Explain the following observations by reference to the bonding present in each of the substances.

i) Ionic substances such as calcium chloride can conduct electricity under certain circumstances.

iii) A metal such as magnesium is malleable.

**62.** **2018. Unit 1. Qn 7a.** Melting temperatures vary down groups and across periods.

ii) Explain why sodium has a lower melting temperature than aluminium.

iii) Explain why silicon has a higher melting temperature than phosphorus.

**63.** **2019. Unit 1. Qn 9d.** Magnesium is a typical metal. Describe the bonding in magnesium and explain why it is ductile. You may include a diagram as part of your answer.

**64.** **2019. Unit 1. Qn 13. b).** ii) The melting temperature of sodium chloride is 1074 K but sodium iodide has a melting temperature of 934 K.

Suggest why the melting temperature of sodium iodide is lower than that of sodium chloride.

**c)** Chlorine forms molecules and ions with other halogens.

i) While chlorine has a boiling temperature of 238 K, the boiling temperature of iodine monochloride is 371 K.

Suggest why the boiling temperature of iodine monochloride is higher than that of chlorine.

**65.** **2014. Unit 5. Qn 4b.** i) Describe the structure of graphite.

**66.** **2019. Unit 3. Qn 2.** The compound AlCl3.NH3 contains both covalent and co-ordinate bonds. Complete the dot-and-cross diagram for this compound.

