Atomic Structure

Question Paper 3

Level	International A Level
Subject	Chemistry
Exam Board	CIE
Topic	Atomic Structure
Sub-Topic	
Paper Type	Theory
Booklet	Question Paper 3

Time Allowed:	**77 minutes**
Score:	**/64**
Percentage:	**/100**

Grade Boundaries:

A*	A	B	C	D	E	U
>85%	777.5%	70%	62.5%	57.5%	45%	<45%

1 Sulfur, S, and polonium, Po, are both elements in Group VI of the Periodic Table.

Sulfur has three isotopes.

(a) Explain the meaning of the term *isotope*.

....

....

....[2]

(b) A sample of sulfur has the following isotopic composition by mass.

isotope mass	32	33	34
% by mass	95.00	0.77	4.23

Calculate the relative atomic mass, A_r, of sulfur to **two** decimal places.

A_r = ...

[2]

(c) Isotopes of polonium, proton number 84, are produced by the radioactive decay of several elements including thorium, Th, proton number 90.

The isotope ^{213}Po is produced from the thorium isotope ^{232}Th.

Complete the table below to show the atomic structures of the isotopes ^{213}Po and ^{232}Th.

	number of		
isotope	protons	neutrons	electrons
^{213}Po			
^{232}Th			

[3]

Radiochemical reactions, such as nuclear fission and radioactive decay of isotopes, can be represented by equations in which the nucleon (mass) numbers must balance and the proton numbers must also balance.

For example, the nuclear fission of uranium-235, ${}^{235}_{92}U$, by collision with a neutron, ${}^{1}_{0}n$, produces strontium-90, xenon-143 and three neutrons.

$$ {}^{235}_{92}U + {}^{1}_{0}n \rightarrow {}^{90}_{38}Sr + {}^{143}_{54}Xe + 3\,{}^{1}_{0}n $$

In this equation, the nucleon (mass) numbers balance because: 235 + 1 = 90 + 143 + (3x1).

The proton numbers also balance because: 92 + 0 = 38 + 54 + (3x0).

(d) In the first stage of the radioactive decay of ${}^{232}_{90}Th$, the products are an isotope of element *E* and an alpha-particle, ${}^{4}_{2}He$.

(i) By considering nucleon and proton numbers only, construct a balanced equation for the formation of the isotope of *E* in this reaction.

$$ {}^{232}_{90}Th \rightarrow \ldots\ldots\ldots\ldots\ldots\ldots + {}^{4}_{2}He $$

Show clearly the nucleon number and proton number of the isotope of *E*.

nucleon number of the isotope of *E* ....

proton number of the isotope of *E* ....

(ii) Hence state the symbol of the element *E*.

.... [3]

[Total: 10]

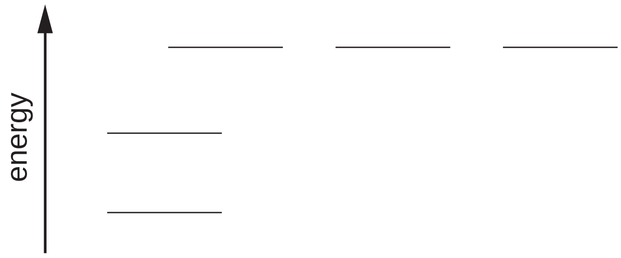
2 In the 19th and 20th centuries, experimental results showed scientists that atoms consist of

a positive, heavy nucleus which is surrounded by electrons.

Then in the 20th century, theoretical scientists explained how electrons are arranged in orbitals around atoms.

(a) The diagram below represents the energy levels of the orbitals present in atoms of the second period (Li to Ne).

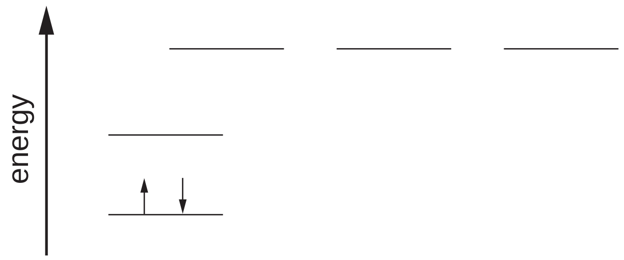
(i) Label the energy levels to indicate the principal quantum number **and** the type of orbital at each energy level.



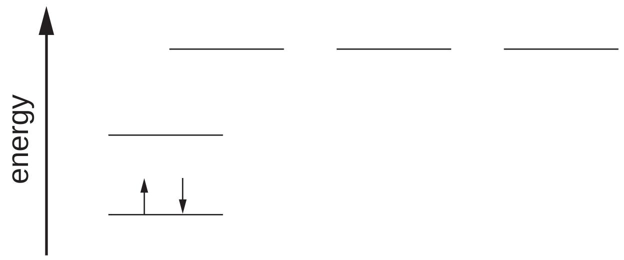
(ii) On the axes below, draw a sketch diagram of **one** of each **different type (shape)** of orbital that is occupied by the electrons in a second-period element.

Label each type.

(iii) Complete the electronic configurations of nitrogen atoms and oxygen atoms on the energy level diagrams below.
Use arrows to represent electrons.



nitrogen



oxygen

[6]

(b) (i) Use the *Data Booklet* to state the value of the first ionisation energy of nitrogen and of oxygen.

N .... kJ mol^{-1} O .... kJ mol^{-1}

(ii) Explain, with reference to your answer to **(a)(iii)**, the relative values of these two ionisation energies.

....

....

....

[3]

[Total: 9]

3 **(a)** Complete the electronic structures of the Cr^{3+} and Mn^{2+} ions.

Cr^{3+} $1s^2 2s^2 2p^6$ ....

Mn^{2+} $1s^2 2s^2 2p^6$ ....

[2]

(b) **(i)** Describe what observations you would make when dilute $KMnO_4$(aq) is added slowly and with shaking to an acidified solution of $FeSO_4$(aq) until the $KMnO_4$ is in a large excess.

....

....

....

....

....

....

(ii) Construct an ionic equation for the reaction that occurs.

....

[4]

(c) By selecting relevant $E^\ominus$ data from the *Data Booklet* explain why acidified solutions of Fe^{2+}(aq) are relatively stable to oxidation by air, whereas a freshly prepared precipitate of $Fe(OH)_2$ is readily oxidised to $Fe(OH)_3$ under alkaline conditions.

relevant $E^\ominus$ values and half equations

....

....

....

....

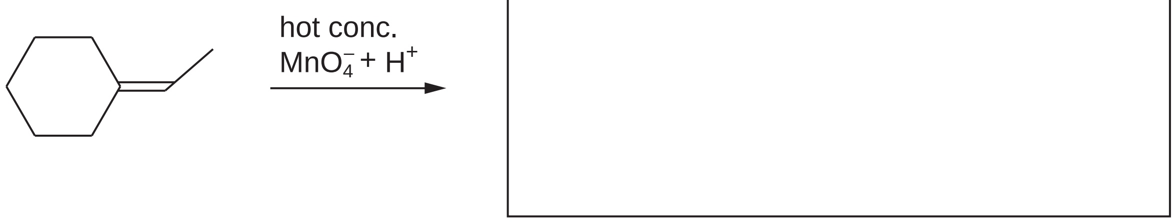
explanation

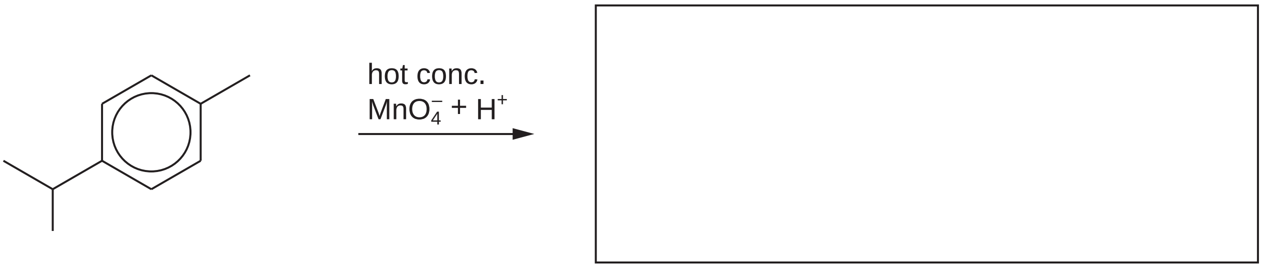
....

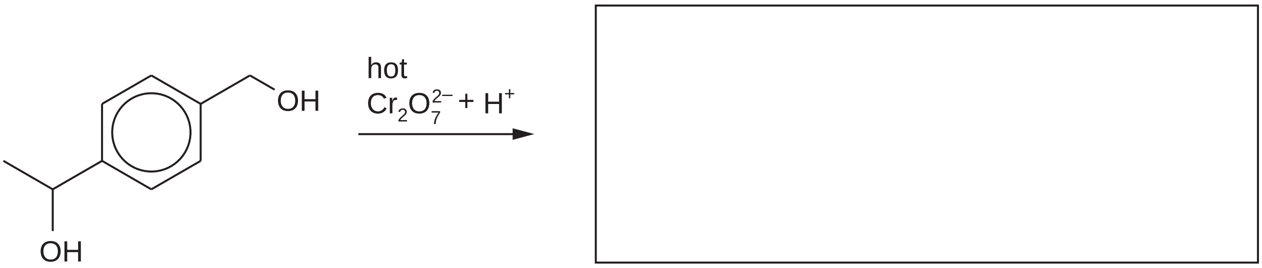
....

[4]

(d) Predict the organic products of the following reactions and draw their structures in the boxes below. You may use structural or skeletal formulae as you wish.

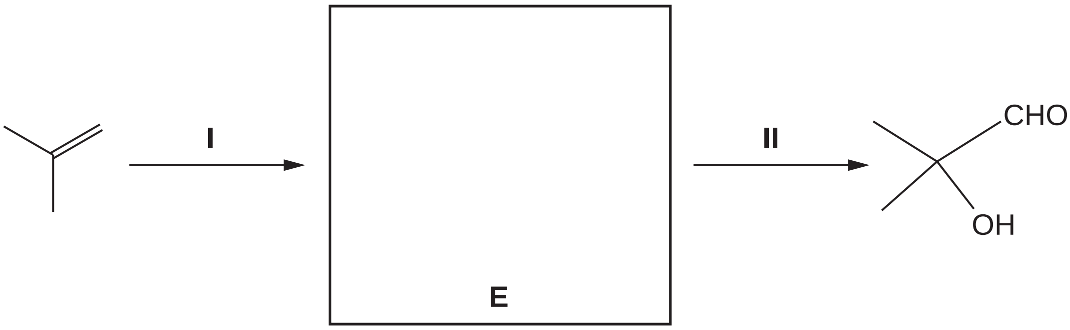






[4]

(e) $KMnO_4$ and $K_2Cr_2O_7$ are the reagents that can be used to carry out the following transformation.



(i) Draw the structure of intermediate **E** in the box above.

(ii) Suggest reagents and conditions for the following.

reaction **I** ....

reaction **II** ....

[3]

[Total: 17]

4 The element magnesium, Mg, proton number 12, is a metal which is used in many alloys which are strong and light.

Magnesium has several naturally occurring isotopes.

(a) What is meant by the term *isotope*?

....

....

....[2]

(b) Complete the table below for two of the isotopes of magnesium.

isotope	number of protons	number of neutrons	number of electrons
^{24}Mg			
^{26}Mg			

[2]

A sample of magnesium had the following isotopic composition:
^{24}Mg, 78.60%; ^{25}Mg, 10.11%; ^{26}Mg, 11.29%.

(c) Calculate the relative atomic mass, A_r, of magnesium in the sample.
Express your answer to an appropriate number of significant figures.

[2]

Antimony, Sb, proton number 51, is another element which is used in alloys.

Magnesium and antimony each react when heated separately in chlorine.

(d) Construct a balanced equation for the reaction between magnesium and chlorine.

.... [1]

When a 2.45 g sample of antimony was heated in chlorine under suitable conditions, 4.57 g of a chloride **A** were formed.

(e) **(i)** Calculate the amount, in moles, of antimony atoms that reacted.

(ii) Calculate the amount, in moles, of chlorine atoms that reacted.

(iii) Use your answers to **(i)** and **(ii)** to determine the empirical formula of **A**.

(iv) The empirical and molecular formulae of **A** are the same.

Construct a balanced equation for the reaction between antimony and chlorine.

.... [5]

(f) The chloride **A** melts at 73.4 °C while magnesium chloride melts at 714 °C.

(i) What type of bonding is present in magnesium chloride?

....

(ii) Suggest what type of bonding is present in **A**.

.... [2]

[Total: 14]

5 Copper and titanium are each used with aluminium to make alloys which are light, strong and resistant to corrosion.

Aluminium, A*l*, is in the third period of the Periodic Table; copper and titanium are both transition elements.

(a) Complete the electronic configuration of aluminium and of titanium, proton number 22.

A*l*	$1s^2$
Ti	$1s^2$

[1]

Aluminium reacts with chlorine.

(b) **(i)** Outline how, starting from aluminium powder, this reaction could be carried out in a school or college laboratory to give a small sample of aluminium chloride. A diagram is not necessary.

....

....

....

(ii) Describe what you would see during this reaction.

....

....

(iii) At low temperatures, aluminium chloride vapour has the formula Al_2Cl_6.
Draw a 'dot-and-cross' diagram to show the bonding in Al_2Cl_6.
Show outer electrons only.
Represent the aluminium electrons by ●.
Represent the chlorine electrons by ***x***.

[6]

Copper forms two chlorides, $CuCl$ and $CuCl_2$.

(c) When copper is reacted directly with chlorine, only $CuCl_2$ is formed.
Suggest an explanation for this observation.

....

.... [1]

Titanium also reacts with chlorine.

(d) When an excess of chlorine was reacted with 0.72 g of titanium, 2.85 g of a chloride **A** was formed.

(i) Calculate the amount, in moles, of titanium used.

(ii) Calculate the amount, in moles, of chlorine atoms that reacted.

(iii) Hence, determine the empirical formula of **A**.

(iv) Construct a balanced equation for the reaction between titanium and chlorine.

....
[4]

(e) At room temperature, the chloride of titanium, **A**, is a liquid which does not conduct electricity.

What does this information suggest about the bonding and structure in **A**?

....

....

.... [2]

[Total: 14]