



Cambridge Assessment International Education
Cambridge International General Certificate of Secondary Education (9–1)

CANDIDATE
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CHEMISTRY

0971/42

Paper 4 Theory (Extended)

May/June 2019

1 hour 15 minutes

Candidates answer on the Question Paper.

No Additional Materials are required.

READ THESE INSTRUCTIONS FIRST

Write your centre number, candidate number and name on all the work you hand in.

Write in dark blue or black pen.

You may use an HB pencil for any diagrams or graphs.

Do not use staples, paper clips, glue or correction fluid.

DO **NOT** WRITE IN ANY BARCODES.

Answer **all** questions.

Electronic calculators may be used.

A copy of the Periodic Table is printed on page 16.

You may lose marks if you do not show your working or if you do not use appropriate units.

At the end of the examination, fasten all your work securely together.

The number of marks is given in brackets [] at the end of each question or part question.

This document consists of **13** printed pages and **3** blank pages.



1 The names of eight substances are given.

aluminium oxide

calcium oxide

ethanol

nitrogen

iron(III) oxide

methane

oxygen

silicon(IV) oxide

Answer the following questions about these substances.

Each substance may be used once, more than once or not at all.

State which substance is:

(a) the main constituent of natural gas

..... [1]

(b) a reactant in respiration

..... [1]

(c) the main constituent of bauxite

..... [1]

(d) a product of photosynthesis

..... [1]

(e) a greenhouse gas

..... [1]

(f) a macromolecular solid.

..... [1]

[Total: 6]

2 (a) ${}_{11}^{22}\text{Na}$, ${}_{11}^{23}\text{Na}$ and ${}_{11}^{24}\text{Na}$ are isotopes of sodium.

(i) Describe how these sodium isotopes are the same and how they are different in terms of the total number of protons, neutrons and electrons in each.

same

.....

different

.....

[3]

(ii) Why do all **three** isotopes have an overall charge of zero?

.....

..... [1]

(iii) Why do all **three** isotopes have the same chemical properties?

.....

..... [2]

(iv) Why do sodium ions have a charge of +1?

.....

..... [1]

(b) Carbon is an element which exists in different forms.

(i) Name **two** forms of the element carbon that have giant covalent structures.

..... and [1]

(ii) Name the oxide of carbon that is a toxic gas.

..... [1]

[Total: 9]

3 This question is about phosphorus and compounds of phosphorus.

(a) Phosphorus has the formula P_4 . Some properties of P_4 are shown.

| | |
|----------------------------|---------------|
| melting point/ $^{\circ}C$ | 45 |
| boiling point/ $^{\circ}C$ | 280 |
| electrical conductivity | non-conductor |
| solubility in water | insoluble |

(i) Name the type of bonding that exists between the atoms in a P_4 molecule.

..... [1]

(ii) Explain, in terms of attractive forces between particles, why P_4 has a low melting point.

.....
 [1]

(iii) Explain why phosphorus is a non-conductor of electricity.

.....
 [1]

(b) Phosphorus, P_4 , reacts with air to produce phosphorus(V) oxide, P_4O_{10} .

(i) Write a chemical equation for this reaction.

..... [2]

(ii) What type of chemical reaction is this?

..... [1]

(c) Phosphorus(V) oxide, P_4O_{10} , is an acidic oxide.

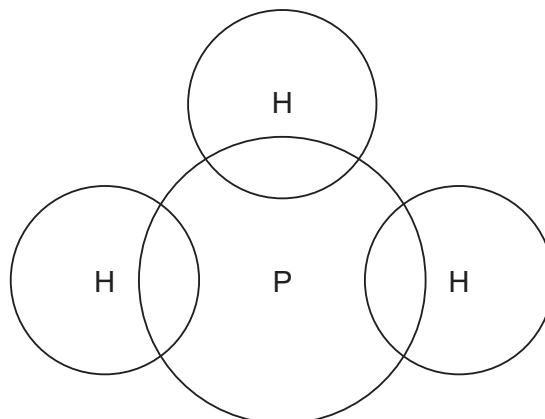
Phosphorus(V) oxide, P_4O_{10} , reacts with aqueous sodium hydroxide to form a salt containing the phosphate ion, PO_4^{3-} . Water is the only other product.

Write a chemical equation for the reaction between phosphorus(V) oxide and aqueous sodium hydroxide.

..... [2]

(d) Phosphine has the formula PH_3 .

Complete the dot-and-cross diagram to show the electron arrangement in a molecule of phosphine. Show outer shell electrons only.



[2]

(e) Phosphine, PH_3 , has a similar chemical structure to ammonia, NH_3 .

Ammonia acts as a base when it reacts with sulfuric acid.

(i) What is meant by the term *base*?

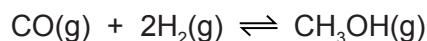
..... [1]

(ii) Write a chemical equation for the reaction between ammonia and sulfuric acid.

..... [2]

[Total: 13]

- 4 Methanol is made industrially by reacting carbon monoxide with hydrogen. The gases react at a temperature of 250 °C and a pressure of 75 atmospheres.



The forward reaction is exothermic.

- (a) Suggest a source of hydrogen for this industrial process.

..... [1]

- (b) Complete the table using only the words *increases*, *decreases* or *no change*.

| | effect on the rate of the reverse reaction | effect on the equilibrium yield of CH ₃ OH(g) |
|----------------------------|--|--|
| adding a catalyst | | no change |
| increasing the temperature | increases | |
| decreasing the pressure | | |

[4]

- (c) Methanol is a member of the homologous series of alcohols.

- (i) State **two** general characteristics of a homologous series.

1

2

[2]

- (ii) Draw the structures of **two** different alcohols, each containing **three** carbon atoms. Show all of the atoms and all of the bonds.

Name these **two** alcohols.

name

name

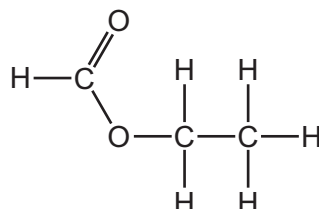
[4]

- (iii) What term is used to describe compounds with the same molecular formula but different structural formulae?

..... [1]

- (d) Alcohols react with carboxylic acids to produce esters.

- (i) The structure of ester **X** is shown.



Name ester **X**.

..... [1]

- (ii) Give the name of the carboxylic acid and the alcohol that react together to produce ester **X**.

carboxylic acid

alcohol

[2]

- (iii) Ester **Y** is different from ester **X** but also has the formula $C_3H_6O_2$.

Draw the structure of ester **Y**. Show all of the atoms and all of the bonds.

..... [2]

[Total: 17]

5 Copper(II) sulfate crystals, $\text{CuSO}_4 \cdot 5\text{H}_2\text{O}$, are hydrated.

Copper(II) sulfate crystals are made by reacting copper(II) carbonate with dilute sulfuric acid.

The equation for the overall process is shown.



step 1 Powdered solid copper(II) carbonate is added to 50.0 cm^3 of 0.05 mol/dm^3 sulfuric acid until the copper(II) carbonate is in excess.

step 2 The excess of copper(II) carbonate is separated from the aqueous copper(II) sulfate.

step 3 The aqueous copper(II) sulfate is heated until the solution is saturated.

step 4 The solution is allowed to cool and crystallise.

step 5 The crystals are removed and dried.

(a) Calculate the maximum mass of the copper(II) sulfate crystals, $\text{CuSO}_4 \cdot 5\text{H}_2\text{O}$, that can form using the following steps.

- Calculate the number of moles of H_2SO_4 in 50.0 cm^3 of $0.05 \text{ mol/dm}^3 \text{ H}_2\text{SO}_4$.

..... mol

- Determine the number of moles of $\text{CuSO}_4 \cdot 5\text{H}_2\text{O}$ that can form.

..... mol

- The M_r of $\text{CuSO}_4 \cdot 5\text{H}_2\text{O}$ is 250.

Calculate the maximum mass of $\text{CuSO}_4 \cdot 5\text{H}_2\text{O}$ that can form.

..... g
[3]

- (b) **Steps 1–5** were done correctly but the mass of crystals obtained was less than the maximum mass.

Explain why.

..... [1]

- (c) State **two** observations that would indicate that the copper(II) carbonate is in excess in **step 1**.

1

2 [2]

- (d) When the reaction in **step 1** is done using lumps of copper(II) carbonate instead of powder, the rate of reaction decreases. All other conditions are kept the same.

Give a reason for this. Explain your answer in terms of particles.

.....

 [2]

- (e) Name a different substance, other than copper(II) carbonate, that could be added to dilute sulfuric acid to produce copper(II) sulfate in **step 1**.

..... [1]

- (f) Name the process used to separate the aqueous copper(II) sulfate from the excess of copper(II) carbonate in **step 2**.

..... [1]

- (g) The solution of aqueous copper(II) sulfate was heated until it was saturated in **step 3**.

- (i) Suggest what is meant by the term *saturated solution*.

.....

 [2]

- (ii) What evidence would show that the solution was saturated in **step 3**?

..... [1]

- (iii) Why should the aqueous copper(II) sulfate **not** be heated to dryness in **step 3**?

..... [1]

[Total: 14]

6 The halogens are the elements in Group VII of the Periodic Table.

(a) Predict the physical state and colour of astatine at room temperature and pressure.

physical state

colour

[2]

(b) When chlorine reacts with aqueous potassium bromide a displacement reaction occurs.

(i) Describe the colour change of the solution.

from to

[2]

(ii) Write a chemical equation for this reaction.

..... [2]

(c) Reactions occur when some aqueous solutions of halogens are added to aqueous solutions of halides.

Use the key to complete the table to show the results of adding halogens to halides.

key

✓ = reaction

x = no reaction

| | | halides | | |
|----------|----------------------|---------|---------|--------|
| | | KCl(aq) | KBr(aq) | KI(aq) |
| halogens | Cl ₂ (aq) | | ✓ | |
| | Br ₂ (aq) | | | |
| | I ₂ (aq) | | | |

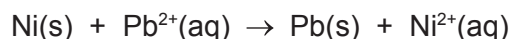
[2]

[Total: 8]

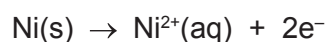
- 7 (a) Displacement reactions occur between metals and metal ions.

Displacement reactions can be used to determine the order of reactivity of metals such as lead (Pb), nickel (Ni), and silver (Ag).

The ionic equation for a displacement reaction is shown.



The ionic half-equations for this reaction are shown.



The ionic half-equations show that electrons are donated by nickel atoms and accepted by lead ions.

- (i) Identify the reducing agent in the displacement reaction. Give a reason for your answer.

reducing agent.....

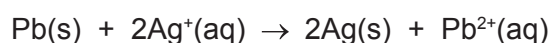
reason.....

[2]

- (ii) What is the general term given to the type of reaction in which electrons are transferred from one species to another?

..... [1]

- (b) The ionic equation for another displacement reaction is shown.



Write the **two** ionic half-equations for this reaction.

1

2

[2]

- (c) Use the information in (a) and (b) to put the **three** metals lead, nickel and silver in order of reactivity.

| | |
|--|----------------|
| | most reactive |
| | ↑ |
| | least reactive |

[1]

- (d) Nickel is a transition element. Nickel is stronger than sodium.

Describe **two** other differences in the physical properties of nickel and sodium.

- 1
- 2

[2]

- (e) Predict **one** difference in the appearance of aqueous solutions of nickel compounds compared to aqueous solutions of sodium compounds.

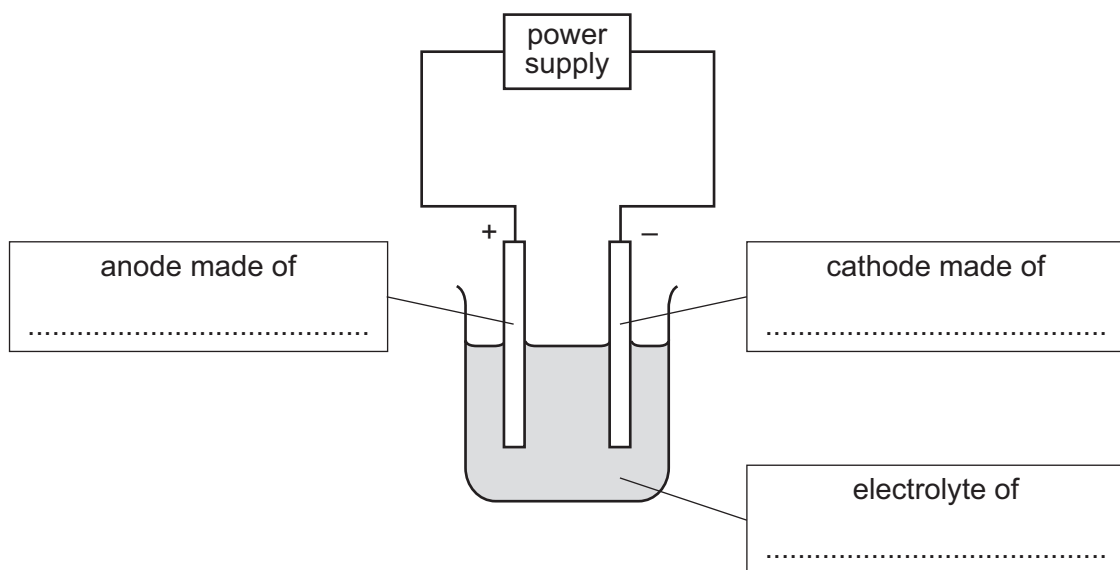
.....

..... [1]

- (f) Copper is refined (purified) by electrolysis. Nickel can be refined using a similar method.

- (i) The diagram shows the refining of nickel by electrolysis.

Complete the labels in the boxes.



[3]

- (ii) Indicate, by writing **N** on the diagram, where nickel is produced.

[1]

[Total: 13]

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The Periodic Table of Elements

| | | Group | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
|----------------------|-----------------------|-----------------------|--------------------------|-----------------------|------------------------|------------------------|------------------------|-----------------------|-------------------------|------------------------|------------------------|----------------------|------------------------|-----------------------|------------------------|-----------------------|-------------------------|-------------------------|------------------------|-------------------------|------------------------|-------------------------|---------------------------|---------------------------|--------------------------|---------------------------|--------------------------|--------------------------|--------------------------|--------------------------|--------------------------|--------------------------|--------------------------|--------------------------|---------------------|
| I | II | III | IV | V | VI | VII | VIII | | | | | VIII | | | | | | | | | | | | | | | | | | | | | | | |
| 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 | 16 | 17 | 18 | | | | | | | | | | | | | | | | | | |
| Li lithium 7 | Be beryllium 9 | B boron 11 | C carbon 12 | N nitrogen 14 | O oxygen 16 | F fluorine 19 | Ne neon 20 | | | | | | | | | | | He helium 4 | | | | | | | | | | | | | | | | | |
| 11 | 12 | 13 | 14 | 15 | 16 | 17 | 18 | 19 | 20 | 21 | 22 | 23 | 24 | 25 | 26 | 27 | 28 | 29 | 30 | 31 | 32 | 33 | 34 | 35 | 36 | | | | | | | | | | |
| Na sodium 23 | Mg magnesium 24 | Al aluminium 27 | Si silicon 28 | P phosphorus 31 | S sulfur 32 | Cl chlorine 35.5 | Ar argon 40 | | | | | | | | | | | K potassium 39 | Ca calcium 40 | Sc scandium 45 | Ti titanium 48 | V vanadium 51 | Cr chromium 52 | Mn manganese 55 | Fe iron 56 | Co cobalt 59 | Ni nickel 59 | Cu copper 64 | Zn zinc 65 | Ga gallium 70 | Ge germanium 73 | As arsenic 75 | Se selenium 79 | Br bromine 80 | Kr krypton 84 |
| 37 | 38 | 39 | 40 | 41 | 42 | 43 | 44 | 45 | 46 | 47 | 48 | 49 | 50 | 51 | 52 | 53 | 54 | 55 | 56 | 57-71 | 72 | 73 | 74 | 75 | 76 | 77 | 78 | 79 | 80 | 81 | 82 | 83 | 84 | 85 | 86 |
| Rb rubidium 85 | Sr strontium 88 | Y yttrium 89 | Zr zirconium 91 | Nb niobium 93 | Mo molybdenum 96 | Tc technetium - | Ru ruthenium 101 | Rh rhodium 103 | Pd palladium 106 | Ag silver 108 | Cd cadmium 112 | In indium 115 | Sn tin 119 | Sb antimony 122 | Te tellurium 128 | I iodine 127 | Xe xenon 131 | Cs caesium 133 | Ba barium 137 | lanthanoids | Hf hafnium 178 | Ta tantalum 181 | W tungsten 184 | Re rhenium 186 | Os osmium 190 | Ir iridium 192 | Pt platinum 195 | Au gold 197 | Hg mercury 201 | Tl thallium 204 | Pb lead 207 | Bi bismuth 209 | Po polonium - | At astatine - | Rn radon - |
| 87 | 88 | 89-103 | 104 | 105 | 106 | 107 | 108 | 109 | 110 | 111 | 112 | 113 | 114 | 115 | 116 | 117 | 118 | 119 | 120 | 121 | 122 | 123 | 124 | 125 | 126 | 127 | 128 | 129 | 130 | 131 | 132 | 133 | 134 | 135 | 136 |
| Fr francium - | Ra radium - | actinoids | Rf rutherfordium - | Db dubnium - | Sg seaborgium - | Bh bohrium - | Hs hassium - | Mt meitnerium - | Ds darmstadtium - | Rg roentgenium - | Cn copernicium - | Fl flerovium - | Lv livermorium - | Uu ununoctium - | Uub unubium - | Uut ununtrium - | Uuq ununquadium - | Uup ununpentium - | Uuq ununhexium - | Uuh ununheptium - | Uuo ununoctium - | Uu113 ununtrium - | Uu114 ununquadium - | Uu115 ununpentium - | Uu116 ununhexium - | Uu117 ununheptium - | Uu118 ununoctium - | Uu119 ununennium - | Uu120 unbinilium - | Uu121 unbinilium - | Uu122 unbinilium - | Uu123 unbinilium - | Uu124 unbinilium - | Uu125 unbinilium - | |

Key

atomic number

atomic symbol

name

relative atomic mass

| | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
|-------------|----|------------------------|----|----------------------|----|---------------------------|----|------------------------|----|-----------------------|----|-----------------------|----|-----------------------|----|-------------------------|----|----------------------|----|-------------------------|----|------------------------|-----|---------------------|-----|------------------------|-----|------------------------|-----|-----------------------|
| lanthanoids | 57 | La lanthanum 139 | 58 | Ce cerium 140 | 59 | Pr praseodymium 141 | 60 | Nd neodymium 144 | 61 | Pm promethium - | 62 | Sm samarium 150 | 63 | Eu europium 152 | 64 | Gd gadolinium 157 | 65 | Tb terbium 159 | 66 | Dy dysprosium 163 | 67 | Ho holmium 165 | 68 | Er erbium 167 | 69 | Tm thulium 169 | 70 | Yb ytterbium 173 | 71 | Lu lutetium 175 |
| actinoids | 89 | Ac actinium - | 90 | Th thorium 232 | 91 | Pa protactinium 231 | 92 | U uranium 238 | 93 | Np neptunium - | 94 | Pu plutonium - | 95 | Am americium - | 96 | Cm curium - | 97 | Bk berkelium - | 98 | Cf californium - | 99 | Es einsteinium - | 100 | Fm fermium - | 101 | Md mendelevium - | 102 | No nobelium - | 103 | Lr lawrencium - |

The volume of one mole of any gas is 24 dm³ at room temperature and pressure (r.t.p.).