Chemical Periodicity – 2021 AS

1. Nov/2021/Paper_22/No.2

(a) Table 1 gives physical data for some of the Period 3 elements.

Table 1

atomic number, *Z*	11	12	13	14	15	16	17
bonding present in element	M						C
first ionisation energy / kJ mol^{-1}	494	736	577	786	1060	1000	1260
maximum oxidation number							+7
anionic radius / nm	–	–	–	0.271	0.212	0.184	0.181

(i) Complete the row in the table labelled 'bonding present in element'.

Use C = covalent, I = ionic, M = metallic, as appropriate. [1]

(ii) Explain the difference between the first ionisation energies of the elements with atomic numbers 11 and 17.

.....

.....

.....

.....

..... [2]

(iii) Explain the difference between the first ionisation energies of the elements with atomic numbers 15 and 16.

.....

.....

.....

.....

..... [2]

(iv) Complete the row in the table labelled 'maximum oxidation number'. [1]

(v) Explain the variation in anionic radius for the elements with atomic numbers 14 to 17.

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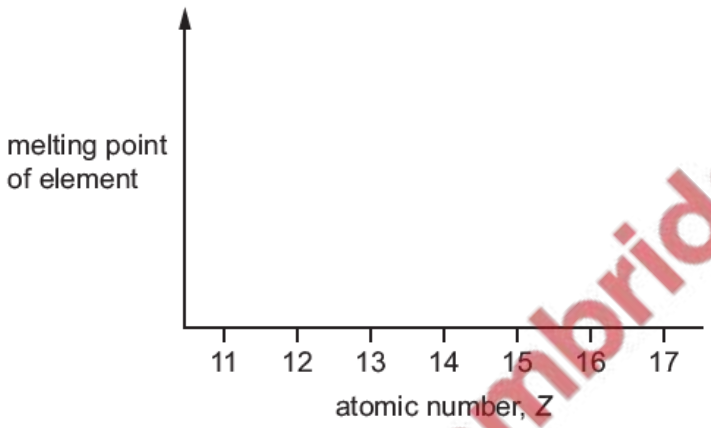
.....

.....

..... [2]

(b) Use the axes to sketch a graph that shows the trend in melting points of the elements with atomic numbers 11 to 17.



[2]

(c) Dmitri Mendeleev published the first Periodic Table in 1869.

Mendeleev used his knowledge of chemical periodicity to propose the properties of gallium, $_{31}Ga$, a Group 13 element.

Table 2 gives some chemical and physical data of elements in Group 13.

Table 2

element	density / g cm^{-3}	boiling point / K	cationic radius / nm
$_{5}B$	2.34	3930	0.020
$_{13}Al$		2470	0.050
$_{31}Ga$	5.91	2400	
$_{49}In$	7.30		0.081
$_{81}Tl$	11.8	1460	0.095

Complete the table by predicting values for the missing data. [3]

(d) Indium and aluminium are elements in Group 13 of the Periodic Table.

Indium has very similar chemical properties to aluminium.

- Indium reacts vigorously with hydrochloric acid to form a colourless gas and a salt in solution.
- Indium oxide, In_2O_3, is amphoteric.
- Gaseous indium bromide has the formula In_2Br_6. This molecule contains coordinate bonds.

(i) Identify the formula of the salt formed when indium reacts with hydrochloric acid.

..... [1]

(ii) Construct an equation for the reaction of In_2O_3 with excess aqueous NaOH.

..... [1]

(iii) Draw a diagram that clearly shows the types of bond present in $In_2Br_6(g)$.

[2]

[Total: 17]

2. Nov/2021/Paper_23/No.3

Phosphorus is a reactive Period 3 element.

(a) Phosphorus has several allotropes. Details of two allotropes are given.

allotrope of phosphorus	formula	melting point / °C
white	P_4	44
red	P	590

(i) White phosphorus and red phosphorus both have covalent bonding.

Suggest the types of structure shown by white phosphorus (P_4) and red phosphorus (P).

Explain why red phosphorus (P) has a higher melting point than white phosphorus (P_4).

structure of P_4 .....

structure of P .....

explanation .....

.....

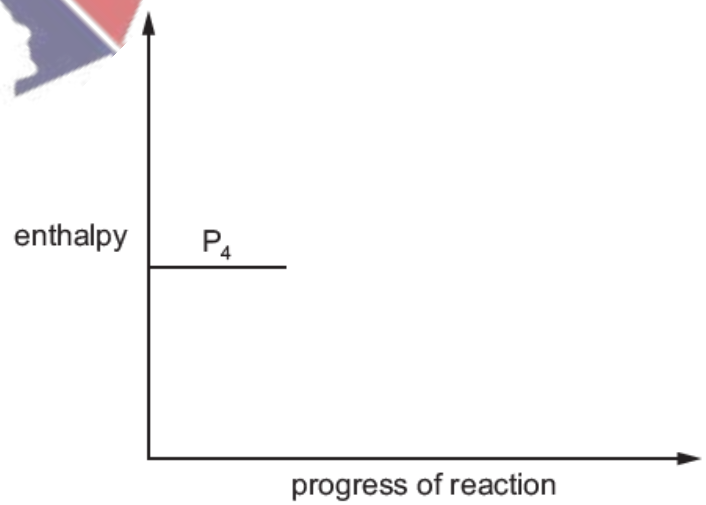
.....

[3]

(ii) Red phosphorus (P) forms when white phosphorus (P_4) is exposed to sunlight.

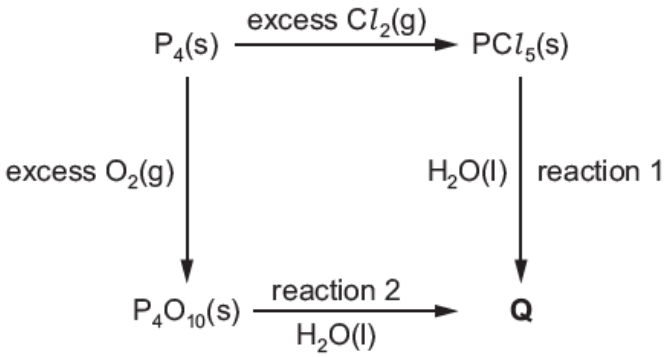
$$\underset{\text{white}}{\tfrac{1}{4}P_4(s)} \rightarrow \underset{\text{red}}{P(s)} \qquad \Delta H = -17.6\,\text{kJ mol}^{-1}$$

Use this information to draw a reaction pathway diagram to show the formation of red phosphorus (P) from white phosphorus (P_4).



[1]

(b) Some reactions of $P_4(s)$ are shown in the reaction scheme.



(i) State the oxidation number of phosphorus in P_4O_{10}.

..... [1]

(ii) Deduce the identity of **Q** and hence construct chemical equations for reactions 1 and 2.

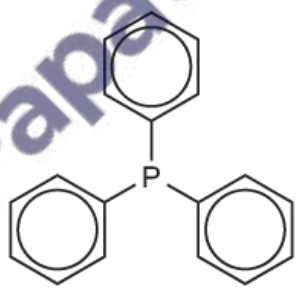
reaction 1 PCl_5 + ...H_2O → .....

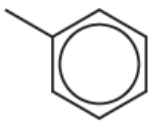
reaction 2 P_4O_{10} + ...H_2O → .....

[2]

(c) Triphenylphosphine is used in a type of reaction known as a *Wittig reaction*.

triphenylphosphine

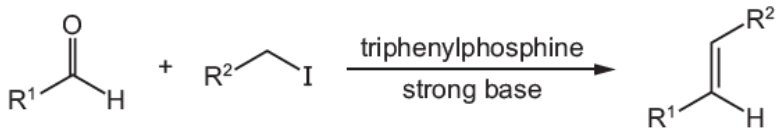


where  = $-C_6H_5$

(i) Give the empirical formula of triphenylphosphine.

..... [1]

In a Wittig reaction, an aldehyde reacts with a halogenoalkane to form an alkene. The conversion is shown in the following unbalanced equation.



Compound **H** can be made from propanal, C_2H_5CHO. Stage 3 in the reaction scheme is a Wittig reaction.

stage 1 $C_2H_5CHO \xrightarrow{NaBH_4}$ **G**

stage 2 **G** $\xrightarrow{\text{red phosphorus and } I_2}$ $C_2H_5CH_2I$

stage 3 (Wittig reaction) $C_2H_5CH_2I + C_2H_5CHO \xrightarrow[\text{strong base}]{\text{triphenylphosphine}}$ **H**

(ii) State the types of reaction that occur in stages 1 and 2.

stage 1 .....

stage 2 .....

[2]

(iii) Draw the structures of **G** and **H** in the boxes provided.

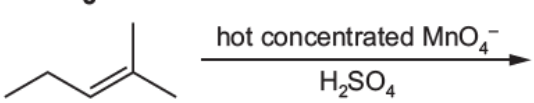
G

H

[2]

(d) Identify the organic products formed when compound **J**, shown below, is heated with hot concentrated acidified manganate(VII) ions.

J



[2]

[Total: 14]

3. June/2021/Paper_11/No.12

Element X is in Period 3. Element X forms a solid oxide Y.

Y reacts with hot concentrated hydrochloric acid. Y reacts with hot aqueous sodium hydroxide to form a compound in which X is part of an anion.

How many p electrons does one atom of X have in its outer shell?

A 0 **B** 1 **C** 2 **D** 3

4. June/2021/Paper_11/No.13

The gaseous products of heating a mixture of $Ca(OH)_2$ and NH_4Cl are passed through solid CaO. A single gaseous product, W, is collected.

A sample of W reacts with $Cl_2(g)$ to produce two gases, X and Y.

X is an element. Y is acidic.

Y reacts with W to produce Z.

What are X and Z?

	X	Z
A	N_2	$CaCl_2$
B	N_2	NH_4Cl
C	O_2	$CaCl_2$
D	O_2	NH_4Cl

5. June/2021/Paper_11/No.35

Which statements are correct going across Period 3 from sodium to chlorine?

1 The charge on the nucleus increases, pulling the electrons closer to it.

2 The radius of the most common ion of each element decreases.

3 The shielding caused by inner electrons decreases, so the outer electrons are pulled closer to the nucleus.

The responses **A** to **D** should be selected on the basis of

A	B	C	D
1, **2** and **3** are correct	**1** and **2** only are correct	**2** and **3** only are correct	**1** only is correct

No other combination of statements is used as a correct response.

6. June/2021/Paper_12/No.13

L and M are elements in Period 3 of the Periodic Table.

- The oxide of L is a solid at room temperature. This oxide has a giant structure.
- The chloride of L does not react with water.
- Argon is the only element in Period 3 with a lower melting point than M.

Which formula represents a compound of elements L and M?

A Al_2S_3 **B** MgS **C** $NaCl$ **D** PCl_5

7. June/2021/Paper_13/No.19

Two oxides of Period 3 elements are added separately to water. Both react to form colourless solutions. One solution is alkaline, the other is acidic.

What could be the two oxides?

A Al_2O_3 and SiO_2

B Al_2O_3 and P_4O_{10}

C Na_2O and P_4O_{10}

D Na_2O and SiO_2

8. June/2021/Paper_13/No.36

Which statements help to explain the increase in melting point from sodium to aluminium?

1 The charge on the metal ion increases.

2 There are more delocalised electrons per metal ion.

3 The radius of the metal ion decreases.

9. June/2021/Paper_23/No.3

Separate samples of **R**, **S**, **T** and **U** are added to cold water. The identity of each sample is unknown. However, each sample is known to be pure and can only be one of $Ba(OH)_2$, $NaCl$, P_4O_{10} or $SiCl_4$.

(a) (i) Use the observations in the table to identify each sample as one of $Ba(OH)_2$, $NaCl$, P_4O_{10} and $SiCl_4$. Write your answers in the table.

	state at room temperature	observations on addition of sample to water	identity of sample
R	solid	alkaline, colourless solution is produced, some white solid remains	
S	solid	white solid disappears, solution is neutral	
T	liquid	misty fumes produced, white solid is made in vigorous reaction	
U	solid	acidic, colourless solution produced in vigorous reaction	

[4]

(ii) Identify the formula of the white solid made when sample **T** reacts with water.

..... [1]

(iii) Name the solution formed when sample **U** reacts with water.

..... [1]

(b) Magnesium oxide and aluminium oxide have properties typical of ceramic materials.

(i) Name **one** physical property typical of ceramic materials.

..... [1]

(ii) Give the formula of another Period 3 oxide which behaves as a ceramic material.

..... [1]

(c) Tungsten oxide, W_xO_y, is used to give colour to ceramic materials.

A sample of W_xO_y contains 79.29% tungsten by mass.

Calculate the empirical formula of W_xO_y.

Show your working.

empirical formula = ...

[3]

[Total: 11]