| **Surname:** | **First Name:** |
|---|---|

| **Current School:** |
|---|

# SHREWSBURY SCHOOL

## SIXTH FORM ENTRANCE EXAMINATION 2021

## CHEMISTRY

**(Time: 1 hour)**

### Instructions to candidates:

- Answer **ALL THIRTY** questions from **SECTION A** on the grid provided **and**
- Answer **TWO** of the **THREE** questions from **SECTION B** in the spaces provided
- **Section A** is worth **30 marks** and **Section B 20 marks**.
- 50 marks in total.
- You may use a calculator.
- You are provided with a **copy of the Periodic table**

# The Periodic Table of the Elements

| Group | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| I | II | | | | | | | | | | III | IV | V | VI | VII | 0 |
| | | | | | | | 1 H Hydrogen 1 | | | | | | | | | 4 He Helium 2 |
| 7 Li Lithium 3 | 9 Be Beryllium 4 | | | | | | | | | | 11 B Boron 5 | 12 C Carbon 6 | 14 N Nitrogen 7 | 16 O Oxygen 8 | 19 F Fluorine 9 | 20 Ne Neon 10 |
| 23 Na Sodium 11 | 24 Mg Magnesium 12 | | | | | | | | | | 27 Al Aluminium 13 | 28 Si Silicon 14 | 31 P Phosphorus 15 | 32 S Sulphur 16 | 35.5 Cl Chlorine 17 | 40 Ar Argon 18 |
| 39 K Potassium 19 | 40 Ca Calcium 20 | 45 Sc Scandium 21 | 48 Ti Titanium 22 | 51 V Vanadium 23 | 52 Cr Chromium 24 | 55 Mn Manganese 25 | 56 Fe Iron 26 | 59 Co Cobalt 27 | 59 Ni Nickel 28 | 64 Cu Copper 29 | 65 Zn Zinc 30 | 70 Ga Gallium 31 | 73 Ge Germanium 32 | 75 As Arsenic 33 | 79 Se Selenium 34 | 80 Br Bromine 35 | 84 Kr Krypton 36 |
| 85 Rb Rubidium 37 | 88 Sr Strontium 38 | 89 Y Yttrium 39 | 91 Zr Zirconium 40 | 93 Nb Niobium 41 | 96 Mo Molybdenum 42 | Tc Technetium 43 | 101 Ru Ruthenium 44 | 103 Rh Rhodium 45 | 106 Pd Palladium 46 | 108 Ag Silver 47 | 112 Cd Cadmium 48 | 115 In Indium 49 | 119 Sn Tin 50 | 122 Sb Antimony 51 | 128 Te Tellurium 52 | 127 I Iodine 53 | 131 Xe Xenon 54 |
| 133 Cs Caesium 55 | 137 Ba Barium 56 | 139 La Lanthanum 57 * | 178 Hf Hafnium 72 | 181 Ta Tantalum 73 | 184 W Tungsten 74 | 186 Re Rhenium 75 | 190 Os Osmium 76 | 192 Ir Iridium 77 | 195 Pt Platinum 78 | 197 Au Gold 79 | 201 Hg Mercury 80 | 204 Tl Thallium 81 | 207 Pb Lead 82 | 209 Bi Bismuth 83 | Po Polonium 84 | At Astatine 85 | Rn Radon 86 |
| Fr Francium 87 | 226 Ra Radium 88 | 227 Ac Actinium 89 | | | | | | | | | | | | | | | |

| | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 140 Ce Cerium 58 | 141 Pr Praseodymium 59 | 144 Nd Neodymium 60 | Pm Promethium 61 | 150 Sm Samarium 62 | 152 Eu Europium 63 | 157 Gd Gadolinium 64 | 159 Tb Terbium 65 | 162 Dy Dysprosium 66 | 165 Ho Holmium 67 | 167 Er Erbium 68 | 169 Tm Thulium 69 | 173 Yb Ytterbium 70 | 175 Lu Lutetium 71 |
| 232 Th Thorium 90 | Pa Protactinium 91 | 238 U Uranium 92 | Np Neptunium 93 | Pu Plutonium 94 | Am Americium 95 | Cm Curium 96 | Bk Berkelium 97 | Cf Californium 98 | Es Einsteinium 99 | Fm Fermium 100 | Md Mendelevium 101 | No Nobelium 102 | Lr Lawrencium 103 |

*58-71 Lanthanoid series
90-103 Actinoid series

Key

a
X
b

a = relative atomic mass
X = atomic symbol
b = proton (atomic) number

## SECTION A

**Answer all questions – circle the correct letter for each question below.**

| | | | | |
|---|---|---|---|---|
| **1** | A | B | C | D |
| **2** | A | B | C | D |
| **3** | A | B | C | D |
| **4** | A | B | C | D |
| **5** | A | B | C | D |
| **6** | A | B | C | D |
| **7** | A | B | C | D |
| **8** | A | B | C | D |
| **9** | A | B | C | D |
| **10** | A | B | C | D |
| **11** | A | B | C | D |
| **12** | A | B | C | D |
| **13** | A | B | C | D |
| **14** | A | B | C | D |
| **15** | A | B | C | D |
| **16** | A | B | C | D |
| **17** | A | B | C | D |
| **18** | A | B | C | D |
| **19** | A | B | C | D |
| **20** | A | B | C | D |
| **21** | A | B | C | D |
| **22** | A | B | C | D |
| **23** | A | B | C | D |
| **24** | A | B | C | D |
| **25** | A | B | C | D |
| **26** | A | B | C | D |
| **27** | A | B | C | D |
| **28** | A | B | C | D |
| **29** | A | B | C | D |
| **30** | A | B | C | D |

Answer **ALL** questions from **SECTION A** on the grid provided**.**

**Question 1**

Which row about a change of state is correct?

| | change of state | energy change | process |
|---|---|---|---|
| A | solid → liquid | heat given out | melting |
| B | gas → liquid | heat taken in | evaporation |
| C | solid → gas | heat taken in | sublimation |
| D | liquid → solid | heat given out | condensing |

**Question 2**

Gases are separated from liquid air by fractional distillation.

The boiling points of four gases are shown.

Which gas is both monoatomic and a liquid at –200 °C?

| | gas | boiling point / °C |
|---|---|---|
| A | argon | –186 |
| B | helium | –269 |
| C | neon | –246 |
| D | nitrogen | –196 |

**Question 3**

Which statement about the atoms of all the isotopes of carbon is correct?

A They are all radioactive.

B They have the same mass.

C They have the same number of neutrons.

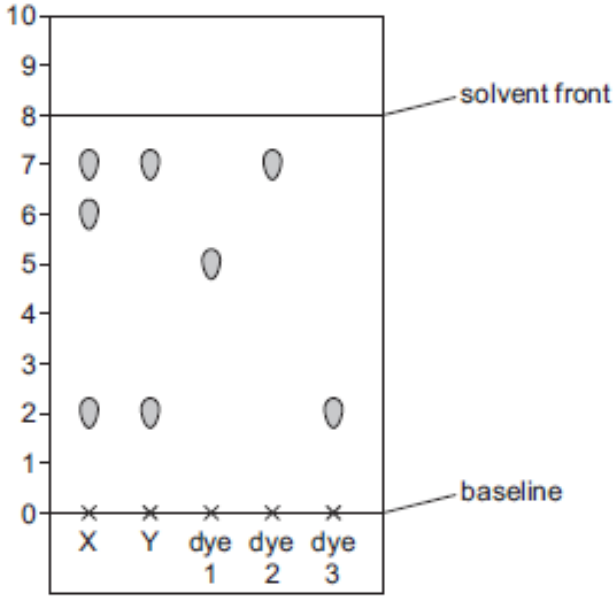
D They have the same number of electrons in the outer shell.

## Question 4

Two different food colourings, X and Y, are tested using chromatography.

Three pure dyes, 1, 2 and 3, are also tested.

The chromatogram is shown.




Which statements are correct?

1 X and Y both contain two or more dyes.

2 Dyes 2 and 3 are present in both X and Y.

3 The $R_f$ of dye 1 is 0.625.

**A** 1 and 2 only **B** 1 and 3 only **C** 1, 2 and 3 **D** 2 and 3 only

## Question 5

Lithium and fluorine react to form lithium fluoride.

A student writes three statements about the reaction.

1 Lithium atoms lose an electron when they react.

2 Each fluoride ion has one more electron than a fluorine atom.

3 Lithium fluoride is a mixture of elements.

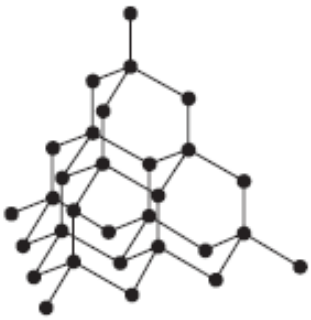
Which statements are correct?

**A** 1 and 2 only **B** 1 and 3 only **C** 2 and 3 only **D** 1, 2 and 3

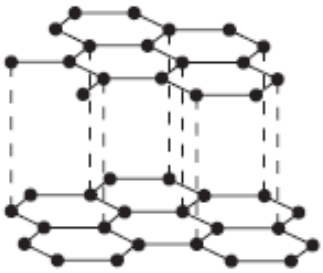
## Question 6

Which diagram represents the structure of silicon(IV) oxide?

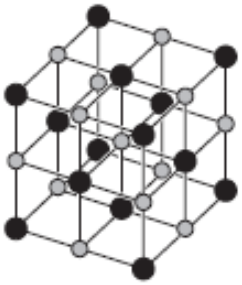
A



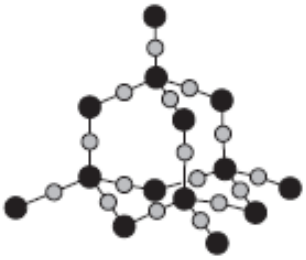
B



C



D



## Question 7

Magnesium oxide has a high melting point.

Carbon dioxide has a low melting point.

Which row identifies the attractive forces that are broken when these compounds are melted?

| | magnesium oxide | carbon dioxide |
|---|---|---|
| A | strong attractions between molecules | weak attractions between atoms |
| B | strong attractions between molecules | weak attractions between molecules |
| C | strong attractions between ions | weak attractions between atoms |
| D | strong attractions between ions | weak attractions between molecules |

## Question 8

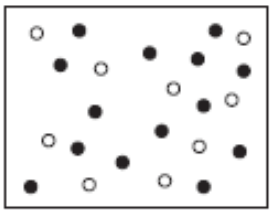
Which gas has the slowest rate of diffusion?

A $H_2$ B $NH_3$ C $CH_4$ D $CO_2$

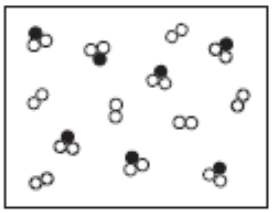
## Question 9

Which diagram represents a mixture of compounds?

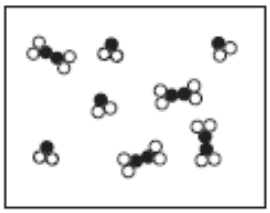
A



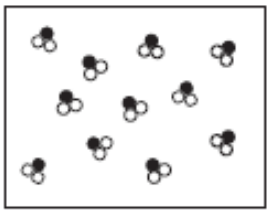
B



C



D



## Question 10

Which process is a physical change?

A burning a piece of magnesium

B dissolving calcium carbonate in hydrochloric acid

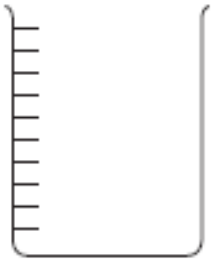
C melting an ice cube

D the rusting of an iron nail

## Question 11

Which diagram shows a burette?

A



B

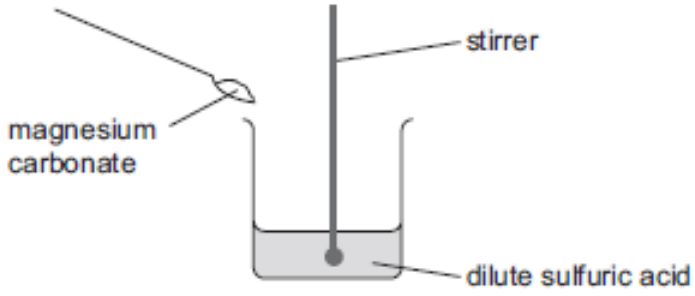
C

D

**Question 12**

A student carries out an experiment to prepare pure magnesium sulfate crystals.

The diagram shows the first stage of the preparation.




He adds magnesium carbonate until no more reacts.

Which process should he use for the next stage?

A crystallisation

B evaporation

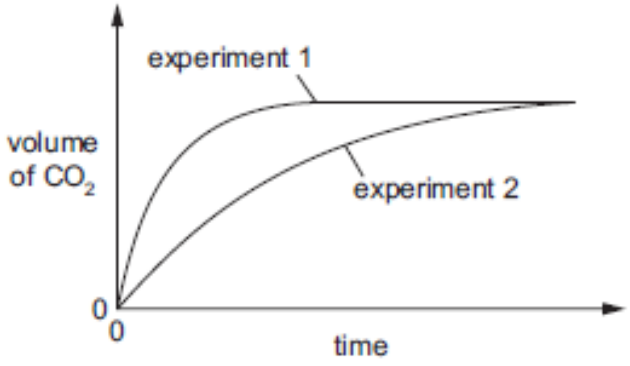
C filtration

D neutralisation

**Question 13**

The graph shows the results of two experiments investigating the rate of reaction between excess calcium carbonate and dilute hydrochloric acid.

In each experiment the volume of carbon dioxide produced is measured at fixed time intervals.




Which statement describes the difference in conditions between experiments 1 and 2?

A In experiment 2 a higher concentration of dilute hydrochloric acid is used.

B In experiment 2 a higher temperature is used.

C In experiment 2 the mass of calcium carbonate is greater.

D In experiment 2 the particle size of calcium carbonate is greater.

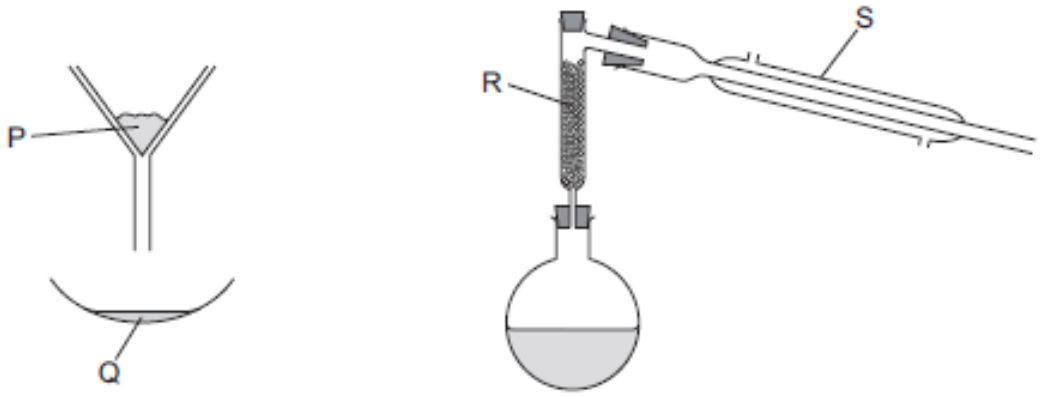
**Question 14**

In which molecule are all the outer shell electrons from each atom used to form covalent bonds?

A $CH_4$ B $Cl_2$ C $H_2O$ D $NH_3$

**Question 15**

The apparatus used to separate a mixture of sand, methanol and ethanol is shown.




Which row identifies the labels on the diagrams?

| | P | Q | R | S |
|---|---|---|---|---|
| A | filtrate | residue | condenser | fractionating column |
| B | filtrate | residue | fractionating column | condenser |
| C | residue | filtrate | condenser | fractionating column |
| D | residue | filtrate | fractionating column | condenser |

**Question 16**

The formula of a hydrocarbon is $C_xH_y$.

The equation for its complete combustion is shown.

$$C_xH_y + 8O_2 \rightarrow 5CO_2 + 6H_2O$$

What are the values of x and y?

| | x | y |
|---|---|---|
| A | 5 | 6 |
| B | 5 | 12 |
| C | 6 | 5 |
| D | 12 | 5 |

**Question 17**

A compound has the formula $XF_2$ and has a relative mass of 70.

What is element X?

A gallium

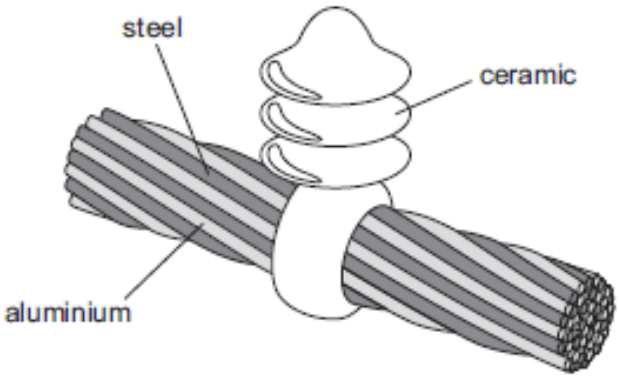
B germanium

C sulfur

D ytterbium

**Question 18**

The diagram shows a section of an overhead power cable.




Which statement explains why a particular substance is used?

A Aluminium has a low density and is a good conductor of electricity.

B Ceramic is a good conductor of electricity.

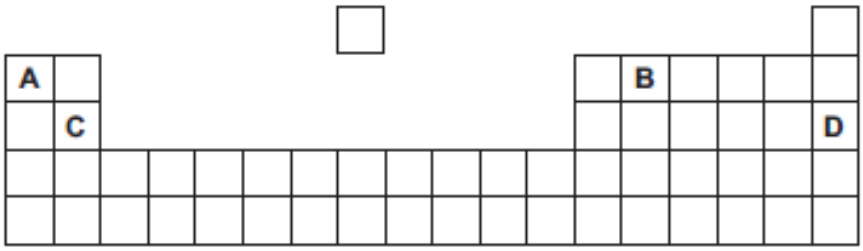
C Steel can rust in damp air.

D Steel is more dense than aluminium.

**Question 19**

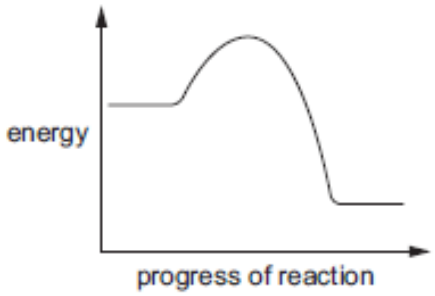
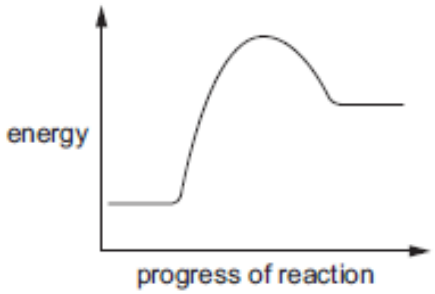
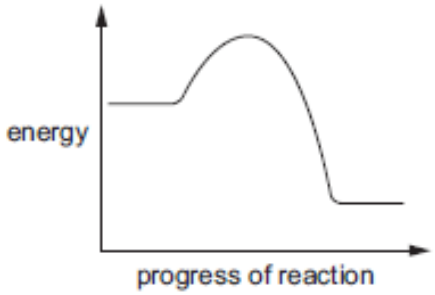
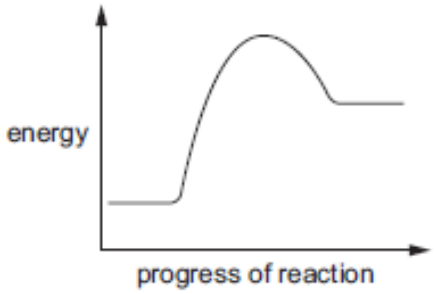
Part of the Periodic Table is shown.

Which element forms an acidic oxide?



**Question 20**

Which row describes an endothermic reaction?

| | energy level diagram | energy transfer |
|---|---|---|
| A |  | energy is transferred from the surroundings to the reaction |
| B |  | energy is transferred from the surroundings to the reaction |
| C |  | energy is transferred from the reaction to the surroundings |
| D |  | energy is transferred from the reaction to the surroundings |

## Question 21

Which process does **not** produce carbon dioxide?

A combustion of a hydrocarbon

B photosynthesis

C reaction between an acid and a metal carbonate

D respiration

## Question 22

Metal X reacts with non-metal Y to form an ionic compound with the formula $X_2Y$.

Which statements are correct?

1 X is in Group I of the Periodic Table.

2 X is in Group II of the Periodic Table.

3 Y is in Group VI of the Periodic Table.

4 Y is in Group VII of the Periodic Table.

A 1 and 3 B 1 and 4 C 2 and 3 D 2 and 4

## Question 23

The table gives some properties of Group IV elements.

| element | density / g/cm$^3$ | boiling point / °C |
|---|---|---|
| carbon | 2.2 | 4827 |
| silicon | | |
| germanium | 5.3 | 2830 |
| tin | 5.8 | 2270 |
| lead | 11.3 | 1755 |

Which row describes the properties of silicon?

| | density / g/cm$^3$ | boiling point / °C |
|---|---|---|
| A | 2.3 | 3265 |
| B | 3.1 | 1997 |
| C | 6.2 | 2920 |
| D | 24.6 | 11682 |

## Question 24

The metal beryllium does not react with cold water.

It reacts with hydrochloric acid but cannot be extracted from its ore by using carbon.

Where is beryllium placed in the reactivity series?

magnesium
A
zinc
B
iron
C
copper
D

## Question 25

Petrol burns in a car engine to produce waste gases which leave through the car exhaust.

One of these waste gases is an oxide of nitrogen.

Which statement describes how this oxide of nitrogen is formed?

A Carbon dioxide reacts with nitrogen in the catalytic converter.

B Nitrogen reacts with oxygen in the car engine.

C Nitrogen reacts with oxygen in the catalytic converter.

D Petrol combines with nitrogen in the car engine.

## Question 26

Propane reacts with chlorine.

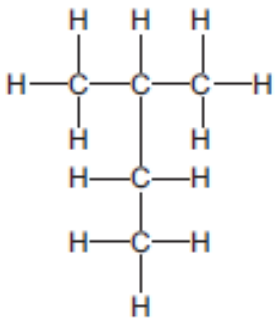
Which row shows a condition required for this reaction and identifies the type of reaction?

| | condition | type of reaction |
|---|---|---|
| A | phosphoric acid catalyst | addition |
| B | phosphoric acid catalyst | substitution |
| C | ultraviolet light | addition |
| D | ultraviolet light | substitution |

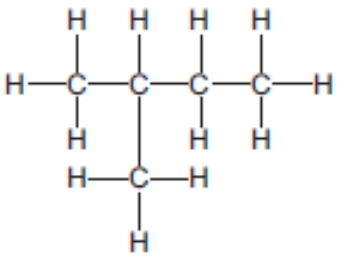
## Question 27

The structures of four organic molecules are shown.

1



2



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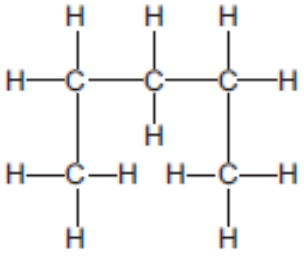

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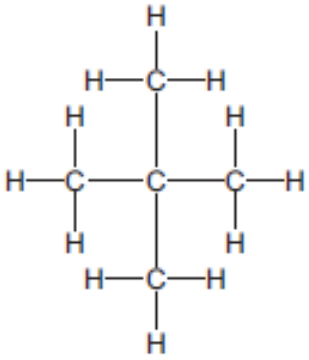


Which molecules are structural isomers of structure 1?

**A** 2 and 4 **B** 2 only **C** 3 and 4 **D** 3 only

## Question 28

What is the balanced chemical equation for the reaction between calcium and water?

**A** $Ca + H_2O \rightarrow CaOH + H_2$

**B** $Ca + H_2O \rightarrow Ca(OH)_2 + H_2$

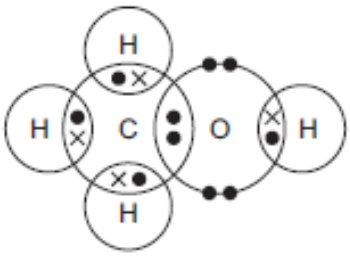
**C** $Ca + 2H_2O \rightarrow CaOH + H_2$

**D** $Ca + 2H_2O \rightarrow Ca(OH)_2 + H_2$

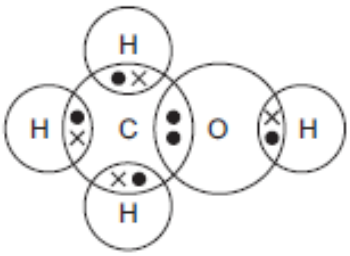
**Question 29**

Which diagram shows the outer shell electron arrangement in a molecule of methanol, $CH_3OH$?

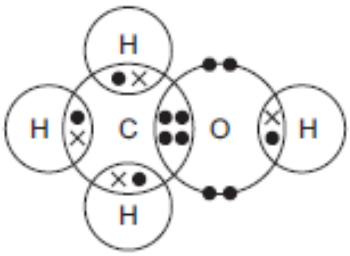
A



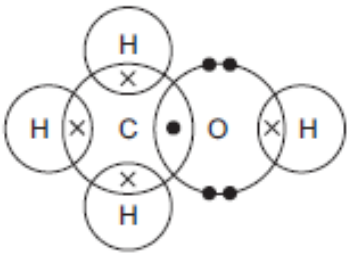

B




C



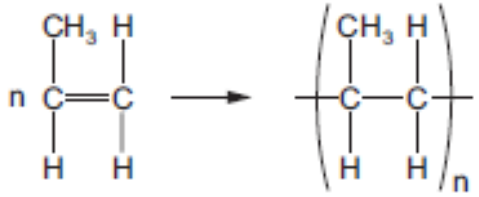

D



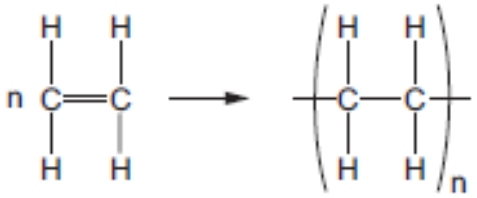

**Question 30**

Which equation represents the formation of poly(propene) from propene?

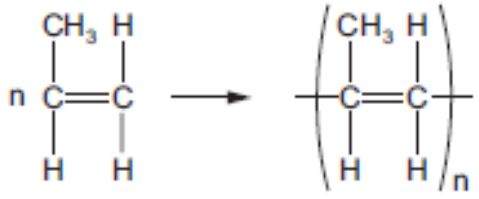
A



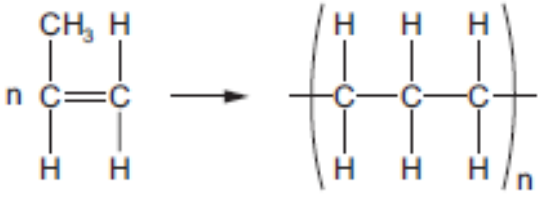

B




C




D



## Section B [Answer **TWO** of the **THREE** questions]

**Question 1**

Ethane is an alkane.

**(a)** Draw the structure of ethane to show all of the atoms and all of the bonds.

[1]

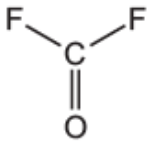
**(b)** Alkanes and alkenes are hydrocarbons.

State the meaning of the term *hydrocarbon*.

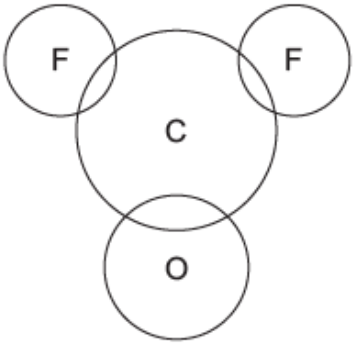
.....

..... [1]

**(c)** Carbonyl fluoride, $COF_2$, is a covalent compound. The structure of a molecule of $COF_2$ is shown.




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




[2]

**(d)** Butyne, $C_4H_6$, is a different hydrocarbon molecule with one carbon-carbon **triple** bond.

Draw a structure of this molecule.

[1]

**(e)** The formula of a carbide ion is $C_2^{2-}$.

What is the formula of compound **sodium carbide**?

…… [1]

**(f)** The table shows the minimum temperature for the reduction of four metal oxides by carbon.

| metal oxide | minimum temperature for reduction by carbon |
|---|---|
| calcium oxide | not reduced at 1530 °C |
| iron(II) oxide | reduced at 650 °C |
| titanium oxide | reduced at 1530 °C |
| zinc oxide | reduced at 720 °C |

Put the four metals in order of their reactivity.
Put the least reactive metal first.

least reactive ⟶ most reactive

[1]

**(g)** Anhydrous copper(II) sulfate, $CuSO_4$, is used to test for water.

**(i)** Describe the change in colour when water is added to anhydrous copper(II) sulfate.

from ..... to .....

[2]

**(ii)** This reaction is reversible.

Describe how this reaction can be reversed.

..... [1]

**[Total: 10]**

## Question 2

Acids have characteristic properties.

**(a)** Hydrochloric acid reacts with magnesium.

Name the products of this reaction and give the observations.

.....

.....

.....

.....

.....

..... [4]

**(b)** The rate of reaction of iron(II) carbonate with hydrochloric acid can be determined by measuring the time taken to produce 20 $cm^3$ of carbon dioxide.

A student measured the time taken to produce 20 $cm^3$ of carbon dioxide at three different temperatures.

In each experiment the student used:

- 1 g of large pieces of iron(II) carbonate
- dilute hydrochloric acid of the same concentration and volume.

The results are shown in the table.

| temperature / °C | time / s |
|---|---|
| 20 | 38 |
| 25 | 30 |
| 30 | 19 |

**(i)** Explain, in terms of particles, what happens to the rate of this reaction when the temperature is increased.

.....

.....

.....

.....

.....

..... [3]

**(ii)** Describe the effect of each of the following on the rate of this reaction at constant temperature.

- Smaller pieces of iron(II) carbonate are used.

All other conditions stay the same.

.....

- The concentration of hydrochloric acid is decreased.

All other conditions stay the same.

.....

[2]

**(c)** The table shows some data for the production of ammonia.

| pressure / atm | temperature / °C | percentage yield of ammonia |
|---|---|---|
| 250 | 350 | 58 |
| 100 | 450 | 28 |
| 400 | 450 | 42 |
| 250 | 550 | 20 |

Deduce the effect on the percentage yield of ammonia of:

- increasing the pressure of the reaction

.....

- increasing the temperature of the reaction.

.....

[1]

**[Total: 10]**

**Question 3**

Soluble salts can be made by adding a metal carbonate to a dilute acid.

**(a)** Give the formula of the dilute acid which reacts with a metal carbonate to form a nitrate salt.

..... [1]

**(b)** Zinc reacts with dilute sulfuric acid to produce aqueous zinc sulfate.

$$Zn(s) + H_2SO_4(aq) \rightarrow ZnSO_4(aq) + H_2(g)$$

Hydrated zinc sulfate crystals are made from aqueous zinc sulfate.

**Step 1** Solid zinc is added to dilute sulfuric acid until zinc is in excess.

**Step 2** Excess zinc is separated from aqueous zinc sulfate by filtration.

**Step 3** Aqueous zinc sulfate is heated until the solution is saturated.

**Step 4** The saturated solution is allowed to cool and crystallise.

**Step 5** The crystals are removed and dried.

**(i)** Name the residue in **step 2**.

..... [1]

**(ii)** In **step 3**, a saturated solution is produced.

Describe what a saturated solution is.

.....

.....

..... [2]

**(iii)** Name **two** compounds each of which react with dilute sulfuric acid to produce aqueous zinc sulfate.

1 .....

2 .....

[2]

**(c)** Ammonia, $NH_3$, is used to produce nitric acid, $HNO_3$. This happens in a three-stage process.

The equation for the reaction in **stage 3** is shown.

$$4NO_2 + 2H_2O + O_2 \rightarrow 4HNO_3$$

Calculate the volume of $O_2$ gas, at room temperature and pressure (r.t.p.), needed to produce 1260 g of $HNO_3$.
Use the following steps.

- Calculate the number of moles of $HNO_3$.

moles of $HNO_3$ = .....

- Deduce the number of moles of $O_2$ that reacted.

moles of $O_2$ = .....

- Calculate the volume of $O_2$ gas that reacts at room temperature and pressure (r.t.p.).

volume of $O_2$ gas = ..... $dm^3$
[4]

**[Total: 10]**

END OF QUESTIONS