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CHEMISTRY **0620/42**

Paper 4 Theory (Extended) **May/June 2024**

1 hour 15 minutes

You must answer on the question paper.

No additional materials are needed.

INSTRUCTIONS

- Answer **all** questions.
- Use a black or dark blue pen. You may use an HB pencil for any diagrams or graphs.
- Write your name, centre number and candidate number in the boxes at the top of the page.
- Write your answer to each question in the space provided.
- Do **not** use an erasable pen or correction fluid.
- Do **not** write on any bar codes.
- You may use a calculator.
- You should show all your working and use appropriate units.

INFORMATION

- The total mark for this paper is 80.
- The number of marks for each question or part question is shown in brackets [ ].
- The Periodic Table is printed in the question paper.

This document has **16** pages. Any blank pages are indicated.

IB24 06_0620_42/4RP
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1 A list of gases is shown.

ammonia
helium
hydrogen
carbon dioxide
carbon monoxide
chlorine
methane
nitrogen dioxide
propene
sulfur dioxide

Answer the following questions about these gases.

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

(a) State **one** gas which:

(i) is the main constituent of natural gas

..... [1]

(ii) is responsible for both photochemical smog **and** acid rain

..... [1]

(iii) is unsaturated

..... [1]

(iv) has monatomic particles

..... [1]

(v) reduces iron(III) oxide in a blast furnace.

..... [1]

(b) Nitrogen dioxide, NO_2, and carbon monoxide are removed from a car exhaust by a catalytic converter.

Write the symbol equation for this reaction.

..... [2]

[Total: 7]

2 A list of five metals is shown.

copper
iron
magnesium
potassium
silver

View solution

(a) All metals form positive ions.

(i) Describe how atoms form positive ions.

..... [1]

(ii) State which of the five metals in the list has the greatest tendency to form positive ions.

..... [1]

(iii) Suggest **one** of the five metals in the list which is **not** likely to show catalytic properties.

..... [1]

(iv) State which of the five metals in the list is a major component of stainless steel.

..... [1]

(b) A student adds a sample of a metal to an aqueous metal salt in a beaker to see if a displacement reaction takes place.

Complete Table 2.1 to show the colour of the solution in the beaker at the start and at the end of the experiment.

View solution

Table 2.1

metal	aqueous solution	colour at the start	colour at the end
magnesium	iron(II) sulfate	green	
silver	copper(II) sulfate		

[3]

(c) Most Group II metals form a gas when placed into cold water. An alkaline solution is also formed.

View solution

(i) Name the gas formed when strontium is added to cold water.

..... [1]

(ii) Name the alkaline solution formed when strontium is added to cold water. View solution

..... [1]

(iii) One Group II metal reacts very slowly when placed in cold water. When heated, the metal reacts with steam to form a white solid.

View solution

Identify this metal and name the white solid formed.

metal .....

white solid .....

[2]

(d) Under certain conditions, iron will react with steam to form an oxide of iron with the formula Fe_3O_4.

Fe_3O_4 reacts with dilute hydrochloric acid to form a mixture of iron(II) and iron(III) salts and water.

Deduce the symbol equation for the reaction between Fe_3O_4 and dilute hydrochloric acid.

View solution

..... [3]

[Total: 14]

3 The symbol equation for the industrial production of ammonia is shown.

$$N_2(g) + 3H_2(g) \rightleftharpoons 2NH_3(g) \qquad \Delta H = -90\,kJ/mol$$

View solution

(a) Name this industrial process.

..... [1]

View solution

(b) State the meaning of ΔH.

..... [1]

(c) State the typical conditions and name the catalyst used in the industrial production of ammonia.

View solution

temperature and units .....

pressure and units .....

catalyst used .....

[3]

View solution

(d) State **two** methods of increasing the rate of this reaction.

1 .....

2 .....

[2]

View solution

(e) The symbol equation for the reaction can be represented as shown in Fig. 3.1.

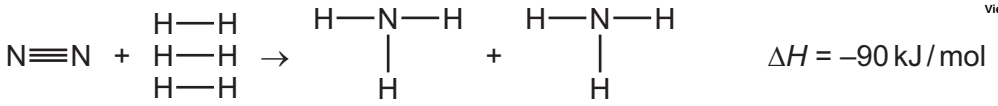

Fig. 3.1

Table 3.1 shows some bond energies.

Table 3.1

bond	N≡N	H–H
bond energy in kJ / mol	945	435

Use the bond energies in Table 3.1 and ΔH to calculate the bond energy of an N–H bond, in kJ / mol.

Use the following steps.

- Calculate the energy needed to break bonds in the reactants.

..... kJ

- Calculate the energy released when bonds form in the products.

..... kJ

- Calculate the energy of an N–H bond.

..... kJ / mol
[3]

(f) An incomplete symbol equation for the preparation of ammonia in the laboratory is shown.

View solution

$$CaO + 2NH_4Cl \rightarrow CaCl_2 + \text{.....} + 2NH_3$$

(i) Complete the symbol equation. [1]

(ii) Name NH_4Cl.

View solution

..... [1]

(iii) Calculate the volume of ammonia, NH_3, measured at room temperature and pressure, which forms when 1.12 g of CaO is heated with excess NH_4Cl.
[M_r: CaO, 56]

View solution

..... cm^3 [3]

[Total: 15]

4 A carboxylic acid reacts with an alcohol to produce an ester and water.

Under certain conditions, this reaction can be reversed so an ester reacts with water to produce a carboxylic acid **X** and an alcohol **Y**.

The reaction reaches an equilibrium.

$$CH_3CH_2COOCH_3 + H_2O \rightleftharpoons \mathbf{X} + \mathbf{Y}$$

The forward reaction is endothermic.

(a) Deduce the empirical formula of the ester.

View solution

..... [1]

(b) Name the ester.

View solution

..... [1]

(c) Name carboxylic acid **X** and draw its displayed formula.

View solution

name .....

displayed formula

[2]

(d) Name alcohol **Y** and give its structural formula.

View solution

name .....

structural formula .....

[2]

(e) Complete Table 4.1 to show the effect, if any, for each change of condition.

View solution

Table 4.1

change of condition	effect on the concentration of carboxylic acid **X** at equilibrium
temperature is decreased	
concentration of $CH_3CH_2COOCH_3$ is decreased	
more alcohol **Y** is added	
a catalyst is added	

[4]

(f) At the beginning of the reaction between the ester and water, no carboxylic acid is present in the reaction mixture.

(i) Suggest how the pH of the reaction mixture changes from the start of the reaction until equilibrium is reached.
Assume alcohols and esters are neutral.

View solution

pH at start of reaction .....

pH at equilibrium .....

[2]

(ii) Identify the ion that causes the change in pH.

View solution

..... [1]

(iii) Name an indicator which can be used to follow the change in pH.

..... [1]

[Total: 14]

View solution

5 Sulfur is a Group VI element.

View solution

(a) A sample of sulfur contains two isotopes, ^{32}S and ^{34}S.

(i) Complete Table 5.1 to show the number of protons and neutrons in one atom of each isotope of sulfur.

Table 5.1

	^{32}S	^{34}S
protons		
neutrons		

[2]

(ii) State why these isotopes have identical chemical properties. View solution

.....

[1]

(iii) State the mass of 6.02×10^{23} atoms of ^{34}S. Include units in your answer. View solution

.....

[1]

(iv) State the name of the amount of substance which contains 6.02×10^{23} atoms. View solution

.....

[1]

(v) Table 5.2 shows the relative abundance of these isotopes of sulfur in the sample. View solution

Table 5.2

atom	^{32}S	^{34}S
relative abundance	95%	5%

Calculate the relative atomic mass of sulfur in this sample to **one** decimal place.

relative atomic mass = ... [2]

(b) Sulfur reacts with magnesium to form magnesium sulfide, MgS, an ionic compound.

View solution

(i) Complete the dot-and-cross diagram in Fig. 5.1 of the ions in magnesium sulfide.

Give the charges on the ions.

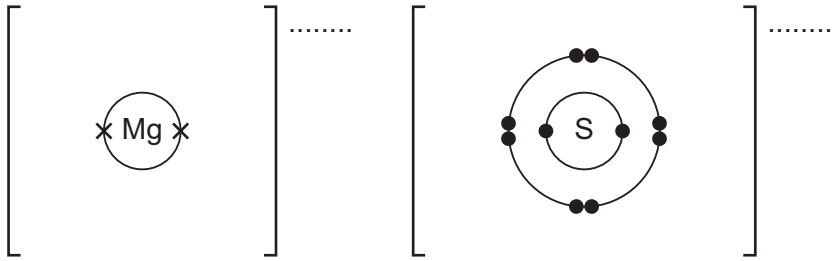

Fig. 5.1

[3]

(ii) State why MgS has a high melting point.

View solution

..... [1]

(iii) State why molten MgS conducts electricity.

View solution

..... [1]

(c) An acid containing sulfur reacts with sodium hydroxide, NaOH, to form a salt and water. The salt has the formula Na_2SO_3.

View solution

(i) Deduce the formula of this acid.

..... [1]

(ii) Deduce the formula of the anion in Na_2SO_3.

View solution

..... [1]

(d) Na_2SO_3 is oxidised by acidified aqueous potassium manganate(VII).

View solution

(i) State what VII refers to in the name potassium manganate(VII).

..... [1]

(ii) State the colour change when this reaction happens.

from ..... to ..... [2]

.

[Total: 17]

View solution

6 Glucose is involved in two processes.

(a) Glucose, $C_6H_{12}O_6$, is made in plants from carbon dioxide and water.

View solution

(i) Name this process.

..... [1]

(ii) Write the symbol equation for this process.

View solution

..... [1]

(iii) State **two** essential conditions needed for this process to happen.

View solution

1 .....

2 .....

[2]

(b) Glucose is converted to ethanol.

View solution

(i) Name this process.

..... [1]

(ii) Name the **other** product formed when glucose is converted to ethanol.

View solution

..... [1]

(c) Ethanol is made by reacting ethene with steam in an industrial process.

View solution

(i) State the conditions and type of catalyst used in this industrial production of ethanol.

temperature and units .....

pressure and units .....

type of catalyst used .....

[3]

(ii) Explain why this reaction is an addition reaction.

..... [1]

View solution

(iii) Complete the dot-and-cross diagram in Fig. 6.1 of a molecule of ethanol.

View solution

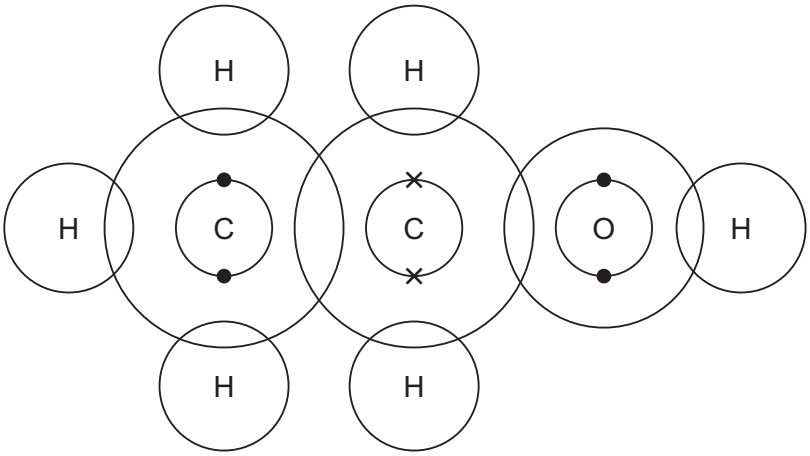

Fig. 6.1

[3]

[Total: 13]

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The Periodic Table of Elements

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

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 dm^3 at room temperature and pressure (r.t.p.).