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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.



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]





- DO NOT WRITE IN THIS MARGIN
- 2 A list of five metals is shown.

copper
iron
magnesium
potassium
silver

- (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.

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.

(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.

..... [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.

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.

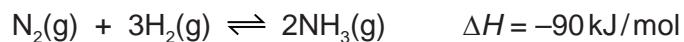
..... [3]

[Total: 14]





- DO NOT WRITE IN THIS MARGIN
- 3 The symbol equation for the industrial production of ammonia is shown.



- (a) Name this industrial process.

..... [1]

- (b) State the meaning of ΔH .

..... [1]

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

temperature and units

pressure and units

catalyst used

[3]

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

1

2

[2]





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

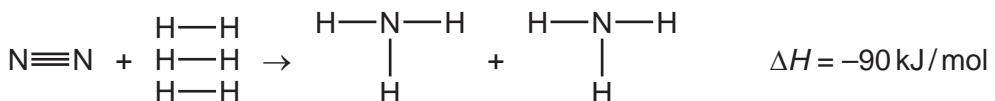


Fig. 3.1

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

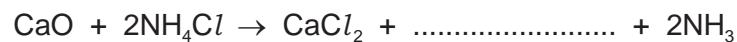
- Calculate the energy of an N–H bond.

..... kJ/mol
[3]





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



(i) Complete the symbol equation.

[1]

(ii) Name NH_4Cl .

..... [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: CaO, 56]

..... cm^3 [3]

[Total: 15]

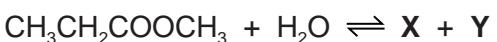




- 4 A carboxylic acid reacts with an alcohol to produce an ester and water.

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.



The forward reaction is endothermic.

- (a) Deduce the empirical formula of the ester.

..... [1]

- (b) Name the ester.

..... [1]

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

name

displayed formula

[2]

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

name

structural formula

[2]





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

Table 4.1

change of condition	effect on the concentration of carboxylic acid X at equilibrium
temperature is decreased	
concentration of $\text{CH}_3\text{CH}_2\text{COOCH}_3$ 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.

pH at start of reaction

pH at equilibrium

[2]

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

..... [1]

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

..... [1]

[Total: 14]





5 Sulfur is a Group VI element.

(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.

..... [1]

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

..... [1]

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

..... [1]

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

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.

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

Give the charges on the ions.

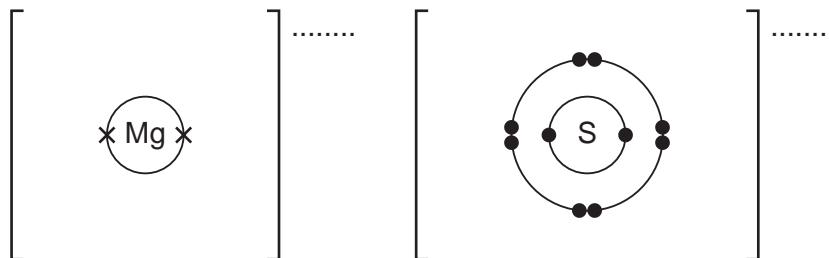


Fig. 5.1

[3]

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

..... [1]

(iii) State why molten MgS conducts electricity.

..... [1]

(c) An acid containing sulfur reacts with sodium hydroxide, NaOH, to form a salt and water. The salt has the formula Na₂SO₃.

(i) Deduce the formula of this acid.

..... [1]

(ii) Deduce the formula of the anion in Na₂SO₃.

..... [1]

(d) Na₂SO₃ is oxidised by acidified aqueous potassium manganate(VII).

(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]





6 Glucose is involved in two processes.

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

(i) Name this process.

..... [1]

(ii) Write the symbol equation for this process.

..... [1]

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

1

2

[2]

(b) Glucose is converted to ethanol.

(i) Name this process.

..... [1]

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

..... [1]

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

(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]





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

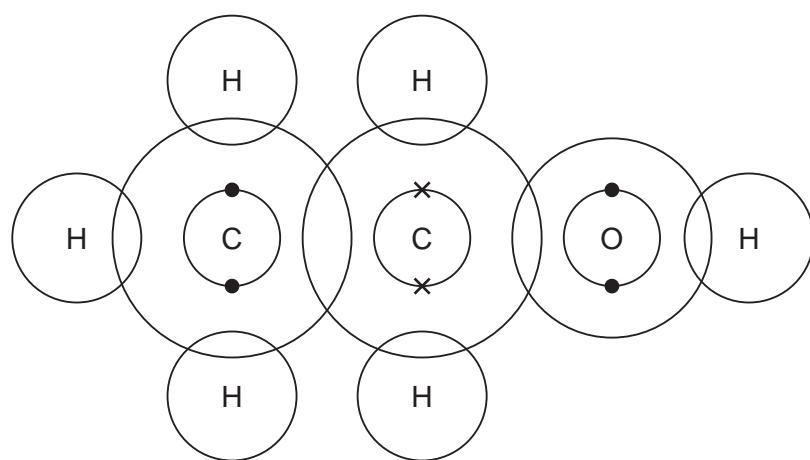


Fig. 6.1

[3]

[Total: 13]



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The Periodic Table of Elements

		Group											
I	II					III		IV		V	VI	VII	VIII
		Key											
3	Li	4 Be	beryllium 9										
7				1	H	hydrogen 1							
11	Na	12 Mg	magnesium 24	20	21 Sc	titanium 45	22 Ti	23 V	24 Cr	25 Mn	26 Fe	27 Co	28 Ni
23													
19	K	20 Ca	calcium 40	39	40 Sr	yttrium 88	39 Y	41 Zr	51 chromium 52	55 manganese 55	56 iron 56	59 cobalt 59	64 nickel 59
39													
37	Rb	38 Sr	strontium 88	40	41 Nb	niobium 93	42 Tc	43 Ru	44 Rh	45 Ruhenium 101	46 Pd	47 Ag	48 Cd
85													
55	Cs	56 Ba	lanthanoids 137	57–71	72 Hf	73 tantalum 181	74 Ta	75 W	76 Re	77 Os	78 Pt	79 Au	80 Hg
133													
87	Fr	88 Ra	actinoids radium –	89–103	104 Rf	105 Db	106 Bh	107 Hs	108 Sg	109 Mt	110 Ds	111 Rg	112 Cn
–													
5	B	6 C	boron 11										
				13	14 Si	12 carbon	14 nitrogen	15 P	16 S	17 Cl	18 F	19 oxygen	20 Ne
				13	14 Al	27 aluminum	28 silicon	31 phosphorus	32 sulfur	33 chlorine 35.5	34 Br	35 Se	36 Kr
				13	14 Ga	70 gallium	73 germanium	75 arsenic	79 selenium	80 tellurium	80 iodine	84 krypton	84 xenon
				13	14 Sn	65 zinc	66 indium	67 tin	79 antimony	128 tellurium	127 iodine	131 radon	–
				13	14 Cd	112 cadmium	115 indium	119 tin	122 antimony	128 tellurium	127 iodine	131 radon	–
				13	14 Pb	106 palladium	108 silver	110 tin	119 antimony	128 tellurium	127 iodine	131 radon	–
				13	14 Bi	106 lead	108 polonium	110 tin	119 antimony	128 tellurium	127 iodine	131 radon	–
				13	14 Po	106 lead	108 polonium	110 tin	119 antimony	128 tellurium	127 iodine	131 radon	–
				13	14 At	106 lead	108 polonium	110 tin	119 antimony	128 tellurium	127 iodine	131 radon	–
				13	14 Rn	106 lead	108 polonium	110 tin	119 antimony	128 tellurium	127 iodine	131 radon	–
				13	14 Og	106 lead	108 polonium	110 tin	119 antimony	128 tellurium	127 iodine	131 radon	–
				13	14 Ts	106 lead	108 polonium	110 tin	119 antimony	128 tellurium	127 iodine	131 radon	–
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				13	14 Lv	106 lead	108 polonium	110 tin	119 antimony	128 tellurium	127 iodine	131 radon	–
				13	14 Nh	106 lead	108 polonium	110 tin	119 antimony	128 tellurium	127 iodine	131 radon	–
				13	14 F	106 lead	108 polonium	110 tin	119 antimony	128 tellurium	127 iodine	131 radon	–
				13	14 Cn	106 lead	108 polonium	110 tin	119 antimony	128 tellurium	127 iodine	131 radon	–
				13	14 Dm	106 lead	108 polonium	110 tin	119 antimony	128 tellurium	127 iodine	131 radon	–
				13	14 Rn	106 lead	108 polonium	110 tin	119 antimony	128 tellurium	127 iodine	131 radon	–
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				13	14 Nh	106 lead	108 polonium	110 tin	119 antimony	128 tellurium	127 iodine	131 radon	–
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				13	14 Lv	106 lead	108 polonium	110 tin	119 antimony	128 tellurium	127 iodine	131 radon	–
				13	14 Nh	106 lead	108 polonium	110 tin	119 antimony</td				

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	europtium 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
89	Th	thorium 232	90	Pa	protactinium 231	91	U	uranium 238	92	Np	neptunium —	93	Pu	plutonium —	94	Am	americium —	95	Cm	curium —	96	Bk	berkelium —	97	Cf	californium —	98	E	einsteinium —	99	Fm	fermium —	100	Md	mendelevium —	101	No	nobelium —	102	Lr	lawrencium —	103	Lu	lawrencium —

The volume of one mole of any gas is 24 dm^3 at room temperature and pressure (r.t.p.).

