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CHEMISTRY

0620/41

Paper 4 Theory (Extended)

May/June 2023

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.

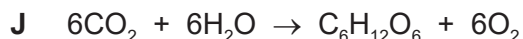
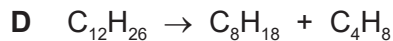
INFORMATION

- 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 Some symbol equations and word equations, **A** to **J**, are shown.



Use the equations to answer the questions that follow.

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

Give the letter, **A** to **J**, for the equation that represents:

(a) a neutralisation reaction [1]

(b) a precipitation reaction [1]

(c) the formation of an ester [1]

(d) photosynthesis [1]

(e) fermentation [1]

(f) cracking. [1]

[Total: 6]

2 (a) The symbols of the elements in Period 2 of the Periodic Table are shown.

Li Be B C N O F Ne

Use the symbols of the elements in Period 2 to answer the questions that follow.
Each symbol may be used once, more than once or not at all.

Give the symbol of the element that:

- (i) makes up approximately 78% of clean, dry air [1]
- (ii) contains atoms with only three electrons in the outer shell [1]
- (iii) contains atoms with only nine protons [1]
- (iv) exists as graphite [1]
- (v) is an alkali metal [1]
- (vi) **only** has an oxidation number of zero. [1]

(b) Boron, B, has two isotopes.

- (i) State the meaning of the term isotopes.

.....
..... [2]

- (ii) Table 2.1 shows the relative masses and the percentage abundances of the two isotopes of boron.

Table 2.1

relative mass of isotope	percentage abundance of isotope
10	20
11	80

Calculate the relative atomic mass of boron to **one** decimal place.

relative atomic mass = [2]

[Total: 10]

3 This question is about ionic and covalent compounds.

- (a) (i) Sodium reacts with oxygen to form the ionic compound sodium oxide.
The electronic configurations of an atom of sodium and an atom of oxygen are shown in Fig. 3.1.



Fig. 3.1

Ions are formed by the transfer of electrons from sodium atoms to oxygen atoms.

Complete the dot-and-cross diagrams in Fig. 3.2 to show the electronic configuration of **one** sodium ion and **one** oxide ion. Show the charges on the ions.

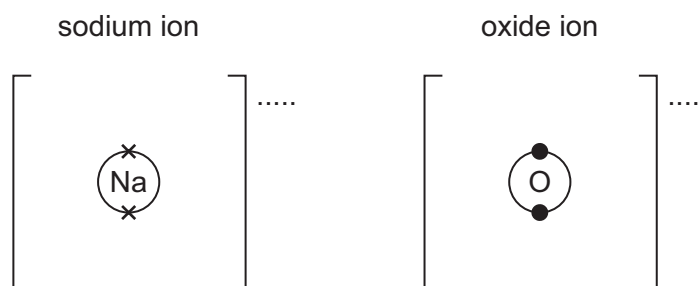


Fig. 3.2

[3]

- (ii) Write the formula of sodium oxide.

..... [1]

(b) Carbon dioxide, CO_2 , is a covalent compound.

Complete the dot-and-cross diagram in Fig. 3.3 to show the electronic configuration in a molecule of carbon dioxide. Show outer shell electrons only.

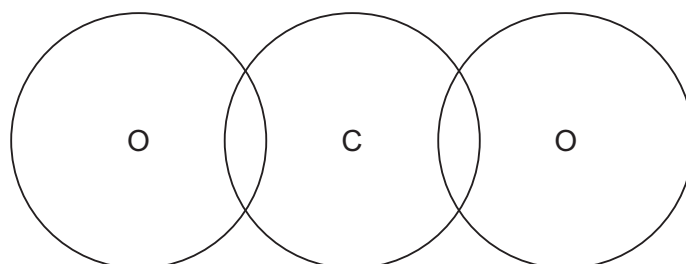


Fig. 3.3

[2]

(c) The melting points of sodium oxide and carbon dioxide are shown in Table 3.1.

Table 3.1

	melting point/°C
sodium oxide	1275
carbon dioxide	-78

(i) Explain, in terms of bonding, why sodium oxide has a high melting point.

.....

.....

.....

..... [2]

(ii) Carbon dioxide has a low melting point.

State the general term for the weak forces that cause carbon dioxide to have a low melting point.

..... [1]

[Total: 9]

- 4 Oxygen is produced by the decomposition of aqueous hydrogen peroxide. Manganese(IV) oxide, MnO_2 , is a catalyst for this reaction.

(a) State the meaning of the term catalyst.

.....
 [2]

- (b) A student adds powdered manganese(IV) oxide to aqueous hydrogen peroxide in a conical flask as shown in Fig. 4.1. The mass of the conical flask and its contents is measured at regular time intervals. The mass decreases as time increases.

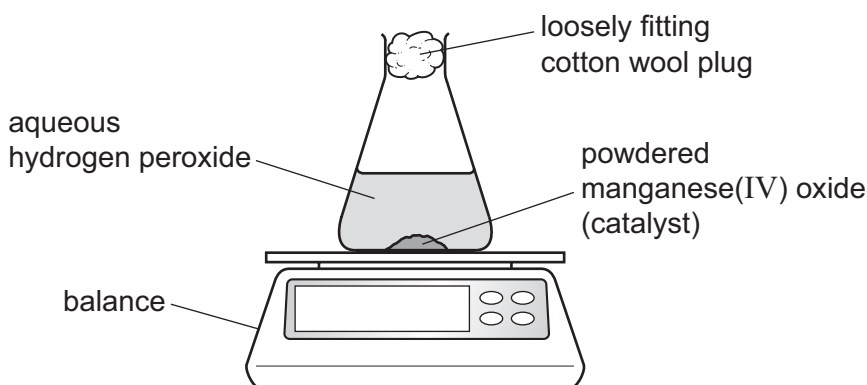


Fig. 4.1

- (i) State why the mass of the conical flask and its contents decreases as time increases.

..... [1]

- (ii) The rate of reaction is highest at the start of the reaction. The rate decreases and eventually becomes zero.

Explain why the rate of reaction is highest at the start of the reaction.

.....
 [1]

- (iii) Explain why the rate of reaction eventually becomes zero.

.....
 [1]

- (c) The experiment is repeated at an increased temperature.
All other conditions stay the same.

Explain in terms of collision theory why the rate of reaction is higher at an increased temperature.

.....

 [3]

- (d) The equation for the decomposition of aqueous hydrogen peroxide, $\text{H}_2\text{O}_2(\text{aq})$, is shown.



50.0 cm³ of a 0.200 mol/dm³ solution of $\text{H}_2\text{O}_2(\text{aq})$ is used.

Calculate the mass of O_2 that forms.
Use the following steps.

- Calculate the number of moles of H_2O_2 used.

..... mol

- Determine the number of moles of O_2 produced.

..... mol

- Calculate the mass of O_2 produced.

..... g
[3]

- (e) State the effect on the mass of oxygen produced if the mass of powdered manganese(IV) oxide catalyst is increased.

..... [1]

- (f) Oxygen can also be produced by the decomposition of mercury(II) oxide, HgO .
The only products of this decomposition are mercury and oxygen.

Write a symbol equation for this decomposition.

..... [2]

[Total: 14]

5 This question is about electricity and chemical reactions.

- (a) The electrolysis of concentrated aqueous potassium bromide using graphite electrodes forms:
- hydrogen at the cathode
 - bromine at the anode.

The electrolyte becomes aqueous potassium hydroxide.

- (i) State what is meant by the term electrolysis.

.....
 [2]

- (ii) State why graphite is suitable for use as an electrode.

..... [1]

- (iii) Write an ionic half-equation for the formation of hydrogen at the cathode.

..... [2]

- (iv) Name the type of particle responsible for the transfer of charge in the conducting wires.

..... [1]

- (v) Name the type of particle responsible for the transfer of charge in aqueous potassium bromide.

..... [1]

- (vi) State the names of the products formed when electricity is passed through **dilute** aqueous potassium bromide using graphite electrodes.

at the anode

at the cathode

[2]

- (b) Bauxite is an ore containing aluminium.

Aluminium is extracted by electrolysis of purified bauxite in molten cryolite using carbon electrodes.

- (i) Name the aluminium compound in purified bauxite.

..... [1]

- (ii) State **two** reasons why cryolite is used in this electrolysis.

1

2

[2]

(iii) The anode is made from carbon.

Explain why the carbon anode has to be replaced regularly.

.....
..... [1]

(c) Hydrogen–oxygen fuel cells can be used to produce electricity in vehicles.

(i) Write the symbol equation for the overall reaction in a hydrogen–oxygen fuel cell.

..... [2]

(ii) State **one** advantage of using hydrogen–oxygen fuel cells instead of petrol in vehicle engines.

..... [1]

[Total: 16]

6 This question is about sulfur and compounds of sulfur.

Sulfur is converted into sulfuric acid, H_2SO_4 , by the Contact process.

The process involves four stages.

stage 1 Molten sulfur is converted into sulfur dioxide.

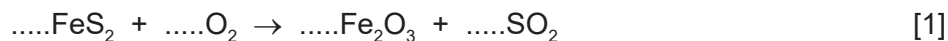
stage 2 Sulfur dioxide reacts with oxygen to form sulfur trioxide.

stage 3 Sulfur trioxide combines with concentrated sulfuric acid to form oleum, $\text{H}_2\text{S}_2\text{O}_7$.

stage 4 Oleum reacts to form concentrated sulfuric acid.

(a) (i) In **stage 1**, iron pyrites, FeS_2 , can be used instead of molten sulfur.
The iron pyrites is heated strongly in air.

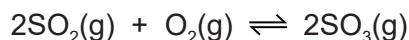
Balance the equation for the reaction occurring when iron pyrites reacts with oxygen in the air.



(ii) Name Fe_2O_3 . Include the oxidation number of iron.

..... [1]

(b) The equation for **stage 2** is shown.



The forward reaction is exothermic.

The reaction is carried out at a temperature of 450°C and a pressure of 2 atm.

Using explanations that do **not** involve cost:

(i) explain why a temperature greater than 450°C is **not** used

.....
..... [1]

(ii) explain why a pressure lower than 2 atm is **not** used.

.....
..... [1]

(c) When sulfuric acid reacts with ammonia the salt produced is ammonium sulfate.

Write the symbol equation for this reaction.

..... [2]

(d) Lead(II) sulfate is an insoluble salt.

Lead(II) sulfate can be made from aqueous ammonium sulfate using a precipitation reaction.

(i) Name a solution that can be added to aqueous ammonium sulfate to produce a precipitate of lead(II) sulfate.

..... [1]

(ii) Write an ionic equation for this precipitation reaction. Include state symbols.

..... [3]

(iii) The precipitate of lead(II) sulfate forms in an aqueous solution.

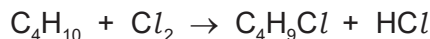
Describe how pure lead(II) sulfate can be obtained from the mixture.

.....
.....
..... [3]

[Total: 13]

7 This question is about organic compounds.

(a) Butane reacts with chlorine in a photochemical reaction.



(i) State the meaning of the term photochemical.

..... [1]

(ii) An organic compound with the formula $\text{C}_4\text{H}_9\text{Cl}$ is formed when one molecule of butane reacts with one molecule of chlorine.

Draw the displayed formulae of **two** possible structural isomers with the formula $\text{C}_4\text{H}_9\text{Cl}$ formed in this reaction.

[2]

(b) The structure of compound **A** is shown in Fig. 7.1.

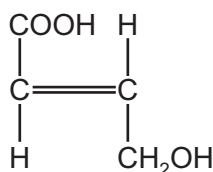


Fig. 7.1

(i) Deduce the molecular formula of compound **A**.

..... [1]

(ii) There are three functional groups in compound **A**.

Name the homologous series of compounds that contain the following functional groups:

$-\text{C}=\text{C}-$

$-\text{OH}$

$-\text{COOH}$

[3]

(iii) State what is observed when compound **A** is added to:

aqueous bromine

aqueous sodium carbonate.

[2]

(iv) Compound **A** can be used as a single monomer to produce two different polymers.

Draw **one** repeat unit of the addition polymer formed from compound **A**.

[2]

(v) Compound **A** can be converted into a dicarboxylic acid.

Name the type of condensation polymer formed from a dicarboxylic acid and a diol.

..... [1]

[Total: 12]

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The Periodic Table of Elements

		Group							
I	II	III	IV	V	VI	VII	VIII		
1	2	3	4	5	6	7	8	9	10
H hydrogen 1	He helium 4	B boron 11	C carbon 12	N nitrogen 14	O oxygen 16	F fluorine 19	Ne neon 20		
Key									
atomic number atomic symbol name relative atomic mass									
3	4	5	6	7	8	9	10	11	12
Li lithium 7	Be beryllium 9	B boron 11	C carbon 12	N nitrogen 14	O oxygen 16	F fluorine 19	Ne neon 20	Ar argon 40	
11	12	13	14	15	16	17	18	19	20
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		
19	20	21	22	23	24	25	26	27	28
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
37	38	39	40	41	42	43	44	45	46
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
55	56	57–71	72	73	74	75	76	77	78
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
87	88	89–103	104	105	106	107	108	109	110
Fr francium —	Ra radium —	actinoids	Rf rutherfordium —	Db dubnium —	Sg seaborgium —	Bh bohrium —	Hs hassium —	Mt meitnerium —	Ds darmstadtium —
81	82	83	84	85	86	87	88	89	90
Tl thallium 204	Pb lead 207	Bi bismuth 209	Po polonium —	At astatine —	Rn radon —	Fr francium —	Ra radium —	Ac actinium —	Th thorium 232
113	114	115	116	117	118	119	120	121	122
Nh nihonium —	Fl flerovium —	Mc moscovium —	Lv livermorium —	Ts tennessine —	Og oganeson —	Uu ununoctium —	Uub unubium —	Uut ununtrium —	Uuq ununquadium —
129	130	131	132	133	134	135	136	137	138
Uuh ununheptium —	Uuq ununquadium —	Uub unubium —	Uut ununtrium —	Uuq ununquadium —	Uub unubium —	Uut ununtrium —	Uuq ununquadium —	Uub unubium —	Uut ununtrium —
153	154	155	156	157	158	159	160	161	162
Uut ununtrium —	Uuq ununquadium —	Uub unubium —	Uut ununtrium —	Uuq ununquadium —	Uub unubium —	Uut ununtrium —	Uuq ununquadium —	Uub unubium —	Uut ununtrium —
173	174	175	176	177	178	179	180	181	182
Uuq ununquadium —	Uub unubium —	Uut ununtrium —	Uuq ununquadium —	Uub unubium —	Uut ununtrium —	Uuq ununquadium —	Uub unubium —	Uut ununtrium —	Uuq ununquadium —
193	194	195	196	197	198	199	200	201	202
Uuq ununquadium —	Uub unubium —	Uut ununtrium —	Uuq ununquadium —	Uub unubium —	Uut ununtrium —	Uuq ununquadium —	Uub unubium —	Uut ununtrium —	Uuq ununquadium —
213	214	215	216	217	218	219	220	221	222
Uuq ununquadium —	Uub unubium —	Uut ununtrium —	Uuq ununquadium —	Uub unubium —	Uut ununtrium —	Uuq ununquadium —	Uub unubium —	Uut ununtrium —	Uuq ununquadium —
233	234	235	236	237	238	239	240	241	242
Uuq ununquadium —	Uub unubium —	Uut ununtrium —	Uuq ununquadium —	Uub unubium —	Uut ununtrium —	Uuq ununquadium —	Uub unubium —	Uut ununtrium —	Uuq ununquadium —
253	254	255	256	257	258	259	260	261	262
Uuq ununquadium —	Uub unubium —	Uut ununtrium —	Uuq ununquadium —	Uub unubium —	Uut ununtrium —	Uuq ununquadium —	Uub unubium —	Uut ununtrium —	Uuq ununquadium —
273	274	275	276	277	278	279	280	281	282
Uuq ununquadium —	Uub unubium —	Uut ununtrium —	Uuq ununquadium —	Uub unubium —	Uut ununtrium —	Uuq ununquadium —	Uub unubium —	Uut ununtrium —	Uuq ununquadium —
293	294	295	296	297	298	299	300	301	302
Uuq ununquadium —	Uub unubium —	Uut ununtrium —	Uuq ununquadium —	Uub unubium —	Uut ununtrium —	Uuq ununquadium —	Uub unubium —	Uut ununtrium —	Uuq ununquadium —

lanthanoids

actinoids

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

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