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CHEMISTRY

0620/41

Paper 4 Theory (Extended)

October/November 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 A list of gases is shown.

ammonia
carbon dioxide
carbon monoxide
ethene
fluorine
oxygen
sulfur dioxide
xenon

Answer the following questions using only the gases from the list.
Each gas may be used once, more than once or not at all.

Give the name of the gas that:

(a) causes acid rain

..... [1]

(b) forms an alkaline solution when dissolved in water

..... [1]

(c) is inert

..... [1]

(d) is a product of photosynthesis

..... [1]

(e) can form a polymer

..... [1]

(f) is produced in the test for nitrate ions.

..... [1]

[Total: 6]

2 Boron and aluminium are Group III elements.

(a) Boron has only two naturally occurring isotopes, ^{10}B and ^{11}B .

Complete Table 2.1 to show the numbers of protons, neutrons and electrons in an atom of ^{11}B .

Table 2.1

number of protons	number of neutrons	number of electrons

[2]

(b) The relative atomic mass of boron to one decimal place is 10.8.

(i) Determine the relative abundance of ^{10}B present in boron. Give your answer as a percentage.

..... % [1]

(ii) Use the relative atomic mass of boron to calculate the number of atoms in 0.540g of boron. Give your answer in standard form.

number of atoms = [2]

(c) Aluminium is extracted from its purified ore as shown in Fig. 2.1.

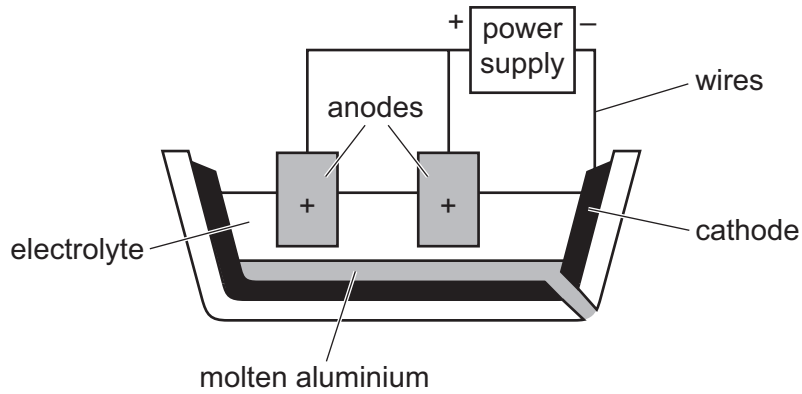


Fig. 2.1

(i) Name the ore of aluminium.

..... [1]

(ii) The electrolyte contains aluminium oxide and one other substance.

Name the other substance and explain why it is used.

name

explanation

..... [2]

(iii) Write the ionic half-equation for the reaction at the cathode.

..... [2]

(iv) Explain why the anodes need frequent replacement.

.....

..... [2]

(d) State **two** physical properties of aluminium that make it suitable for use in overhead electrical cables.

1

2

[2]

(e) Explain the apparent unreactivity of aluminium.

.....
 [2]

(f) Aluminium reacts with fluorine to form aluminium fluoride, AlF_3 , an ionic compound.

(i) Write the symbol equation for this reaction.

..... [2]

(ii) Complete Fig. 2.2 to show the electronic configuration of one aluminium ion and one fluoride ion.
 Show the charges on the ions.

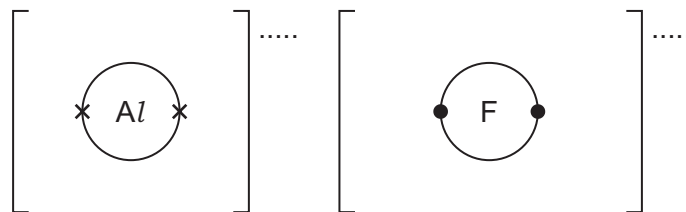


Fig. 2.2

[3]

[Total: 21]

3 Order of reactivity can be determined by displacement reactions.

(a) A student investigates the reactivities of four metals by carrying out a series of experiments.

Each of the metals lead, manganese, silver and zinc are added separately to aqueous metal nitrates of the other metals.

(i) Table 3.1 shows some of the results.

Table 3.1

aqueous solution	lead Pb	manganese Mn	silver Ag	zinc Zn
lead(II) nitrate		✓		
manganese(II) nitrate				
silver nitrate	✓	✓		✓
zinc nitrate	x	x		

key

✓ = displacement reaction occurs

x = displacement reaction does not occur

Complete Table 3.1 and place the four metals in their order of reactivity with the most reactive first.

1 most reactive

2

3

4

[3]

(ii) Suggest why the metal nitrates and not the metal sulfates of these four metals are used as the aqueous solutions.

..... [1]

(iii) Write the symbol equation for the reaction between zinc and silver nitrate.

..... [2]

(b) The reactivity of Group VII elements can be investigated experimentally.

A student bubbles chlorine gas into a test-tube containing aqueous potassium bromide.

(i) Describe the colour change seen in the test-tube.

from to [2]

(ii) Complete the ionic equation for this reaction.

Include state symbols.

..... +Br⁻(aq) → + [3]

(iii) The reactivity trend seen in Cl, Br and I applies to all the elements in Group VII.

Use the Periodic Table to identify the Group VII element which **cannot** displace any other Group VII elements.

..... [1]

[Total: 12]

- 4 Aqueous hydrogen peroxide, H_2O_2 , slowly forms water and oxygen at room temperature and pressure, r.t.p. This reaction is catalysed by manganese(IV) oxide.

The equation is shown.



- (a) State the test for oxygen gas.

test

observations

[1]

- (b) A student investigates the rate of formation of oxygen gas when manganese(IV) oxide is added to aqueous hydrogen peroxide.

The volume of oxygen gas formed is measured at regular time intervals at r.t.p. The results are plotted onto the graph in Fig. 4.1.

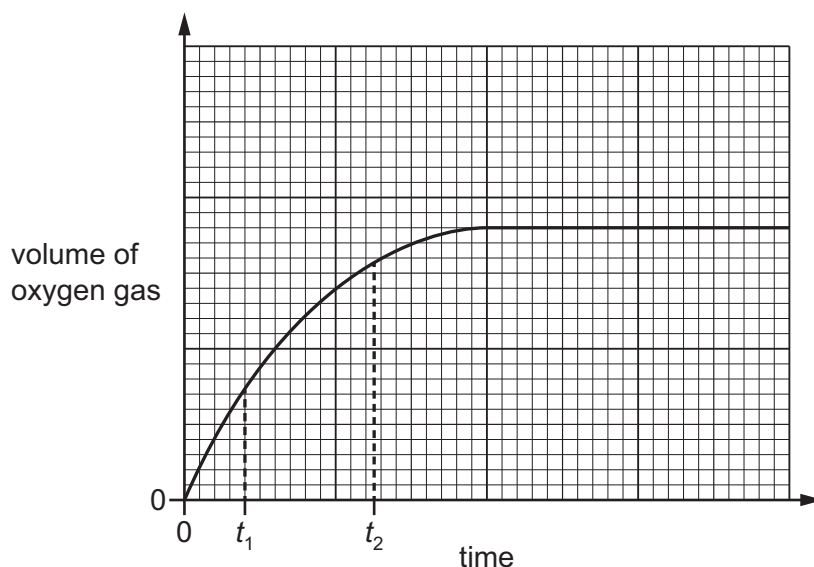


Fig. 4.1

- (i) State how the graph in Fig. 4.1 shows the rate of reaction at time t_2 , is lower than at time t_1 .

..... [1]

- (ii) Explain, using collision theory, why the rate of reaction at time t_2 is lower than at time t_1 .

.....

.....

..... [2]

- (iii) On Fig. 4.1, sketch the graph obtained when the experiment is repeated using aqueous hydrogen peroxide at a higher temperature. All other conditions remain the same. [2]

- (c) Manganese(IV) oxide is added to 20 cm³ of aqueous hydrogen peroxide. The total volume of oxygen gas produced is 72 cm³ at r.t.p.



Calculate the concentration of the aqueous hydrogen peroxide in g/dm³ using the following steps.

- Calculate the number of moles of oxygen gas produced.

..... mol

- Determine the number of moles of hydrogen peroxide which reacts.

..... mol

- Calculate the concentration of aqueous hydrogen peroxide in mol/dm³.

..... mol/dm³

- Calculate the concentration of aqueous hydrogen peroxide in g/dm³.

..... g/dm³
[5]

- (d) Suggest the identity of one **other** metal oxide which also catalyses this reaction.

..... [1]

[Total: 12]

- 5 Methane reacts with steam to produce hydrogen gas.



The reaction takes place at 1000 °C and 100 kPa pressure.

- (a) The reaction is reversible and reaches an equilibrium in a closed system.

State **two** features of an equilibrium.

1

2

[2]

- (b) State and explain, in terms of equilibrium, what happens to the concentration of hydrogen when:

- (i) the pressure is increased

.....

..... [2]

- (ii) the temperature is increased

.....

..... [2]

- (iii) a catalyst is used.

.....

..... [2]

- (c) Methane is a greenhouse gas which contributes to global warming.

- (i) Name a greenhouse gas found in clean, dry air.

..... [1]

- (ii) Explain, in terms of thermal energy, how greenhouse gases cause global warming.

.....

.....

.....

.....

..... [3]

[Total: 12]

6 Ethanol is manufactured by **two** methods:

method 1 fermentation of aqueous glucose

method 2 catalytic addition of steam to an alkene.

(a) Method 1 takes place at room temperature and pressure.

State **two** other conditions needed in method 1.

1

2

[2]

(b) (i) State the typical temperature and pressure used in method 2.

temperature °C

pressure kPa

[2]

(ii) Name the alkene used in method 2.

..... [1]

(iii) State why the reaction in method 2 is referred to as an addition reaction.

..... [1]

(c) The catalyst in method 2 is phosphoric acid, H_3PO_4 . Dilute phosphoric acid is a weak acid which contains phosphate ions, PO_4^{3-} .

(i) State what is meant by the term acid.

..... [1]

(ii) State the meaning of weak in the term weak acid.

..... [1]

(iii) Determine the oxidation number of phosphorus in the PO_4^{3-} ion.

Show your working.

oxidation number = [2]

(d) Give **one** advantage of each method of production of ethanol.

method 1

method 2

[2]

(e) Ethanol can be converted to ethanoic acid by reacting it with an acidified oxidising agent.

(i) Name the acidified oxidising agent.

..... [1]

(ii) State, in terms of redox, what type of reagent ethanol is in this reaction.

..... [1]

(f) Ethanoic acid reacts with calcium to form a salt and one other product.

(i) Name the salt.

..... [1]

(ii) Write the formula of the salt.

..... [1]

(iii) Identify the other product.

..... [1]

[Total: 17]

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The Periodic Table of Elements

		Group															
I	II	III	IV	V	VI	VII	VIII					VIII					
1	2	3	4	5	6	7	8	9	10					11			
Li lithium 7	Be beryllium 9	B boron 11	C carbon 12	N nitrogen 14	O oxygen 16	F fluorine 19	Ne neon 20					He helium 4					
11	12	13	14	15	16	17	18					19					
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					39					
19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36
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	Cu copper 64	Zn zinc 65	Ga gallium 70	Ge germanium 73	As arsenic 75	Se selenium 79	Br bromine 80	Kr krypton 84
37	38	39	40	41	42	43	44	45	46	47	48	49	50	51	52	53	54
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	Ag silver 108	Cd cadmium 112	In indium 115	Sn tin 119	Sb antimony 122	Te tellurium 128	I iodine 127	Xe xenon 131
55	56	57–71	72	73	74	75	76	77	78	79	80	81	82	83	84	85	86
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	Au gold 197	Hg mercury 201	Tl thallium 204	Pb lead 207	Bi bismuth 209	Po polonium —	At astatine —	Rn radon —
87	88	89–103	104	105	106	107	108	109	110	111	112	113	114	115	116	117	118
Fr francium —	Ra radium —	actinoids	Rf rutherfordium —	Db dubnium —	Sg seaborgium —	Bh bohrium —	Hs hassium —	Mt meitnerium —	Ds darmstadtium —	Rg roentgenium —	Cn copernicium —	Nh nihonium —	Fl flerovium —	Mc moscovium —	Lv livermorium —	Ts tennessine —	Og oganeson —

Key

atomic number
atomic symbol
name
relative atomic mass

1	H
hydrogen	1

lanthanoids

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 —

actinoids

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