

Answer ALL the questions. Write your answers in the spaces provided.

1. Iron is a typical transition metal.

(a) (i) Complete the electronic configurations for

Fe²⁺: [Ar]

Fe³⁺: [Ar]

(1)

(ii) Use your answer to (i) to explain which of the ions, Fe²⁺ or Fe³⁺, would be expected to be the more stable.

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(1)

(iii) Explain why both the hydrated Fe²⁺ and Fe³⁺ ions are coloured.

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(3)

(iv) Suggest why the hydrated Fe²⁺ and Fe³⁺ ions have different colours.

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(1)



(b) The compound ammonium iron(III) sulphate, $\text{NH}_4\text{Fe}(\text{SO}_4)_2 \cdot 12\text{H}_2\text{O}$, contains the pale purple $[\text{Fe}(\text{H}_2\text{O})_6]^{3+}$ ion. When dissolved in water, the resulting solution is yellow.

(i) Name the $[\text{Fe}(\text{H}_2\text{O})_6]^{3+}$ ion, and draw it to show its shape clearly. Include the charge on the ion.

Name.....

Diagram

(2)

(ii) The yellow ion in aqueous solutions of iron(III) salts has the formula $[\text{Fe}(\text{H}_2\text{O})_5\text{OH}]^{2+}$. Write the equation to show how this ion is formed when hydrated iron(III) salts are dissolved in water. State symbols are **not** required.

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(1)

(iii) What could be added to an aqueous solution of an iron(III) salt to ensure that $[\text{Fe}(\text{H}_2\text{O})_6]^{3+}$ is present, **not** $[\text{Fe}(\text{H}_2\text{O})_5\text{OH}]^{2+}$?

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(1)



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(c) (i) State what you **see** when sodium hydroxide solution is added to a solution of hydrated iron(II) ions, $[\text{Fe}(\text{H}_2\text{O})_6]^{2+}$. Give the **ionic** equation for the reaction.

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(2)

(ii) State and explain what you **see** when the mixture obtained in (c)(i) is left to stand in air for a period of time.

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(2)



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(d) (i) A red, water-soluble compound, **R**, contains potassium, iron and oxygen only.

When 1.98 g of **R** (molar mass 198 g mol^{-1}) is dissolved in water and acidified with dilute sulphuric acid, the solution will oxidise 4.56 g of iron(II) sulphate (molar mass 152 g mol^{-1}). **All** of the iron in the product mixture is present as Fe^{3+} .

Calculate the amount (moles) of **R** reduced and the amount (moles) of the iron(II) sulphate oxidised. Hence calculate the oxidation state of iron in compound **R**.

(4)

(ii) **R** contains one mole of iron per mole of compound. What is the formula of **R**?

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(1)

Q1

(Total 19 marks)

5

Turn over



N 3 3 9 1 2 A 0 5 2 0

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2. Safflower oil is sold as a dietary supplement. Over 75% of its fat contains the polyunsaturated fatty acid linolenic acid, $C_{17}H_{29}COOH$.

(a) Give the mechanism for the reaction of bromine with a $C=C$ bond.

Use $\begin{array}{c} \diagup \\ C=C \\ \diagdown \end{array}$ to represent the unsaturated part of the molecule.

(3)

(b) The $C=C$ bonds in linolenic acid react with iodine in a similar way to their reaction with bromine. 100 g of linolenic acid (molar mass 278 g mol^{-1}) reacts with 274 g of iodine, I_2 .

(i) Calculate how many $C=C$ bonds a molecule of linolenic acid contains.

(3)



(ii) Give the structural formula of the **fat** derived from linolenic acid, $C_{17}H_{29}COOH$.
You do **not** need to show the structure of the $C_{17}H_{29}$ group.

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(1)

(iii) Give the equation to show the conversion of the fat in (ii) into a soap.

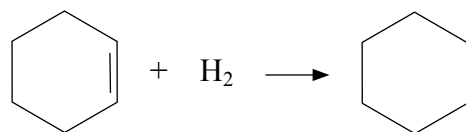
(2) Q2

(Total 9 marks)

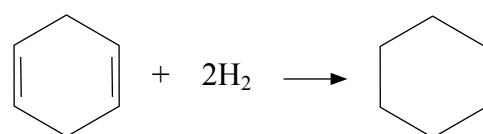


3. The hexagonal ring structure of benzene was first suggested by Kekulé in 1865, but the nature of the bonding was not elucidated until the 1930s. This question concerns aspects of the structure of benzene.

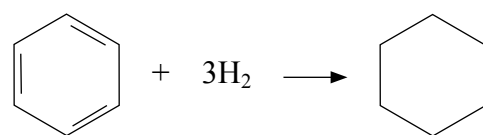
(a) The enthalpy of hydrogenation of cyclohexene to give cyclohexane is -120 kJ mol^{-1}



and that of cyclohexa-1,4-diene is -240 kJ mol^{-1} .



(i) What would you expect the value of the enthalpy of hydrogenation to be for the hypothetical molecule cyclohexa-1,3,5-triene, on the basis of these data?



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(1)



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(ii) The hydrogenation enthalpy of benzene to give cyclohexane is -208 kJ mol^{-1} .

Use your result from (i) and this information to draw an enthalpy level diagram to show that benzene is thermodynamically more stable than the hypothetical cyclohexa-1,3,5-triene. Label the stabilisation energy on your diagram.

energy



(2)

(iii) Explain in terms of **bonding** why benzene would be less reactive with bromine than the hypothetical cyclohexa-1,3,5-triene.

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(3)



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(b) Benzene reacts with a mixture of concentrated nitric and sulphuric acids to give nitrobenzene. The temperature should be no higher than 55 °C.

(i) Give the **overall** equation for the reaction.

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(1)

(ii) Give the mechanism of the reaction, including the equation for the formation of the electrophile.

(4)

(iii) Why must the temperature of the reaction be kept below 55 °C?

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(1)



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(c) Ethanol, $\text{CH}_3\text{CH}_2\text{OH}$, and phenol, $\text{C}_6\text{H}_5\text{OH}$, both contain hydroxyl groups as their functional group. However, they do **not** always react similarly.

(i) Write TWO equations to show one reaction of ethanol and one reaction of phenol where they react in a similar manner.

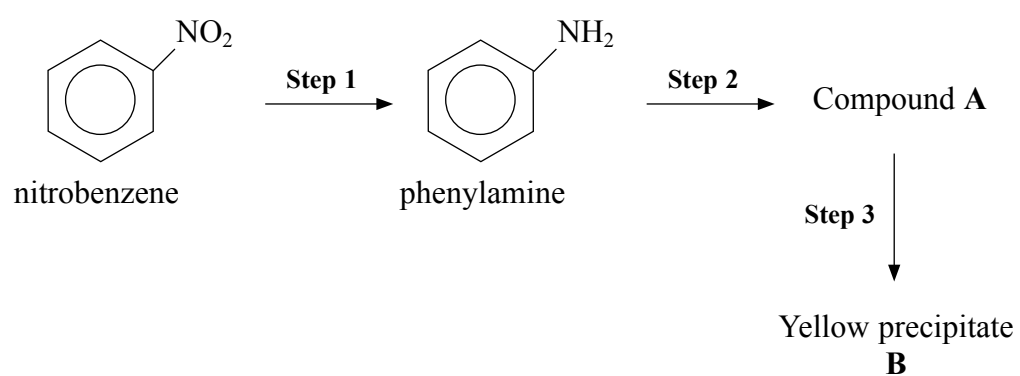
(2)

(ii) Give an equation for a reaction of phenol which is **not** shown by ethanol.

(2)



(d) This question concerns the reaction scheme shown below.



(i) Give the reagents needed for the reduction of nitrobenzene in **step 1**.

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 (1)

(ii) In **step 1** when reduction is complete, the reaction mixture must be made alkaline to liberate the phenylamine product.

Give the equation for the reaction that occurs when the alkali is added.

(2)

(iii) In **step 2**, a mixture of sodium nitrite and hydrochloric acid is used at a temperature between 0 °C and 10 °C.

Explain why the reaction mixture must **not** be cooler or warmer than these limits.

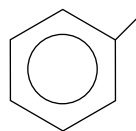
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 (2)



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(iv) Complete the structure of the cation in compound **A**, showing **all** the bonds.



(1)

(v) In **step 3**, compound **A** reacts with phenol. What conditions are necessary?

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(1)

(vi) Draw the structure of compound **B**, showing **all** the bonds.

(2)

(Total 25 marks)

Q3

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13

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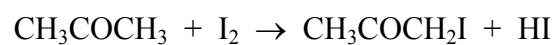


N 3 3 9 1 2 A 0 1 3 2 0

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4. Propanone reacts with iodine in the presence of an acid catalyst as shown below.



The rate equation is of the form

$$\text{rate} = k[\text{CH}_3\text{COCH}_3]^a[\text{I}_2]^b[\text{H}_3\text{O}^+]^c$$

In an experiment designed to find the values of **a**, **b** and **c**, propanone was reacted with iodine in the presence of an acid catalyst at constant temperature.

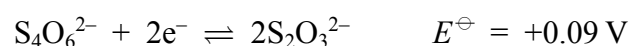
(a) Explain, in terms of the **rate equation**, why the temperature must be kept constant.

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(1)

(b) In such an experiment, at various times the concentration of iodine in quenched samples of the reaction mixture was determined by titration of the iodine with sodium thiosulphate solution.

(i) Use the half-equations given to derive the equation for the reaction between thiosulphate ions and iodine, and show that it is feasible.



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(2)

(ii) The samples of the reaction mixture are quenched using sodium hydrogencarbonate solution, which neutralises the acid catalyst. Why is quenching required?

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(1)



(iii) Sodium hydroxide is **not** used to neutralise the acid catalyst because propanone reacts with iodine and sodium hydroxide. Give the equation for this reaction.

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(2)

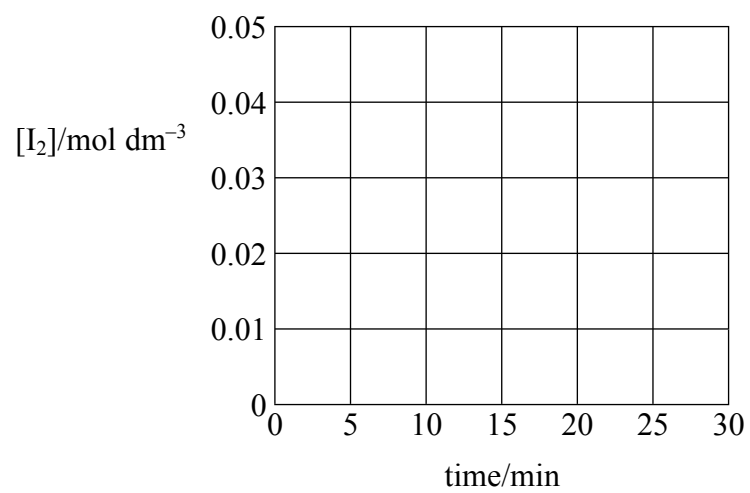
(c) With propanone in large excess, its concentration and that of the acid catalyst are virtually constant during the reaction, so that the rate equation becomes

$$\text{rate} = k'[\text{I}_2]^b$$

$$\text{where } k' = k[\text{CH}_3\text{COCH}_3]^a[\text{H}_3\text{O}^+]^c$$

(i) An experiment was carried out as described above and the results are given below. Plot these data on the axes provided.

time/min	5	10	15	20	25
$[\text{I}_2]/\text{mol dm}^{-3}$	0.045	0.036	0.027	0.019	0.010



(2)



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(ii) What is the order of reaction with respect to iodine? Justify your answer.

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(2)

(iii) Another experiment was carried out with the concentration of propanone being doubled, but with all other concentrations and the temperature being the same as before. The slope of the line doubled.

What is the order of reaction with respect to propanone?

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(1)

(iv) On the basis of the reaction orders determined above, explain why the reaction between propanone and iodine must take place in at least two steps.

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(2)

(d) **Briefly** outline another method by which the rate of change of iodine concentration could be followed.

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(2)

Q4

(Total 15 marks)

TURN OVER FOR QUESTION 5



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5. Propanal, $\text{CH}_3\text{CH}_2\text{CHO}$, and propanone, CH_3COCH_3 , are isomeric carbonyl compounds.

(a) Give ONE chemical test to distinguish between these two compounds. Give the result of the test for each compound.

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(3)

(b) Give the number of peaks, and the relative areas under the peaks, in the nmr spectra of propanal and propanone.

Propanal

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Propanone

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(3)

(c) Explain why you would **not** easily be able to distinguish propanal from propanone using their infra-red spectra, without the use of standard comparison spectra.

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(1)

Q5

(Total 7 marks)

TOTAL FOR PAPER: 75 MARKS

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THE PERIODIC TABLE

Period **1** **2** **3** **4** **5** **6** **7** **0** Group

1	H Hydrogen 1
2	He Helium 2

Key	
Molar mass g mol ⁻¹	Symbol
Name	Atomic number

1	H Hydrogen 1
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7	Li Lithium 3	9	Be Beryllium 4	11	B Boron 5	12	C Carbon 6	13	Al Aluminium 13	14	N Nitrogen 7	15	O Oxygen 8	16	F Fluorine 9	17	Ne Neon 10																				
23	Na Sodium 11	24	Mg Magnesium 12	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	63.5	Cu Copper 29	65.4	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	99	Tc Technetium 43	101	Ru Ruthenium 44	103	Rh Rhodium 45	106	Pd Palladium 46	108	Ag Silver 47	110	Cd Cadmium 48	112	In Indium 49	115	Sn Tin 50	119	Sb Antimony 51	122	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	210	Po Polonium 84	210	At Astatine 85	222	Rn Radon 86		
223	Fr Francium 87	226	Ra Radium 88	227	Ac Actinium 89																																

140	Ce Cerium 58	141	Pr Praseodymium 59	144	Nd Neodymium 60	147	Pm Promethium 61	150	Sm Samarium 62	152	Eu Europium 63	157	Gd Gadolinium 64	159	Tb Terbium 65	163	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	231	Pa Protactinium 91	238	U Uranium 92	237	Np Neptunium 93	242	Pu Plutonium 94	243	Am Americium 95	247	Cm Curium 96	245	Bk Berkelium 97	251	Cf Californium 98	254	Es Einsteinium 99	253	Fm Fermium 100	256	Md Mendelevium 101	254	No Nobelium 102	257	Lr Lawrencium 103