Organic Synthesis

Question Paper 2

Level	International A Level
Subject	Chemistry
Exam Board	CIE
Topic	Organic Synthesis
Sub-Topic	
Paper Type	Theory
Booklet	Question Paper 2

Time Allowed: **72 minutes**

Score: **/60**

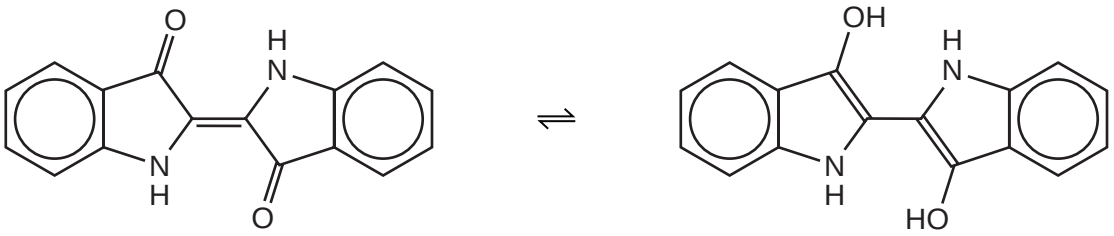
Percentage: **/100**

Grade Boundaries:

A*	A	B	C	D	E	U
>85%	777.5%	70%	62.5%	57.5%	45%	<45%

1 Indigo is the dye used in blue jeans. Although originally extracted from plants of the type *indigofera*, it is now almost entirely made artificially.

Indigo is insoluble in water but this disadvantage can be overcome by converting it into the water-soluble colourless leuco-indigo. If cloth soaked in a solution of leuco-indigo is left to dry in the air, the leuco-indigo is converted into the insoluble blue indigo, which is precipitated out onto the fibres of the cloth.



indigo leuco-indigo

(a) Give the molecular formula of indigo.

.....

(ii) Name **three** functional groups in indigo.

.....

[3]

(b) What *type of reaction* is the conversion of indigo into leuco-indigo?

.....

(ii) Suggest a laboratory reagent for this reaction.

.....

[2]

(c) Suggest **two** chemical tests that could be used to distinguish between indigo and leuco-indigo. Write your answers in the following table.

test	reagents and conditions	observation with indigo	observation with leuco-indigo
1			
2			

[5]

(d) When indigo is heated with hydrogen and a nickel catalyst, compound **A**, $C_{16}H_{28}N_2O_2$, is formed.

(i) Suggest a structure for **A**.

(ii) Calculate the volume of hydrogen, measured at room temperature and pressure, that would have been absorbed if 2.50 g of indigo had undergone this reaction.

volume = ...dm^3
[3]

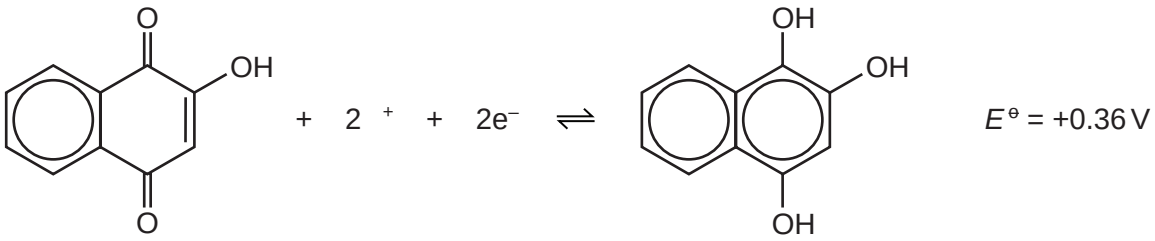
(e) Suggest the structure of the product formed when indigo reacts with an excess of $Br_2(aq)$.

[3]

[Total: 16]

2 Lawsone is the dye that is extracted from the henna plant, *Lawsonia inermis*. Although its natural colour is yellow, lawsone reacts with the proteins in hair and skin to produce the characteristic brown henna colour.

Lawsone can readily be reduced to 1,2,4-trihydroxynaphthalene, compound **A**.



lawsone 1,2,4-trihydroxynaphthalene, **A**

(a) Name **three** functional groups in lawsone.

.....

.....

(ii) Describe a reaction (reagent with conditions) that you could use to distinguish lawsone from compound **A**.
Describe the observations you would make with **both** compounds.

.....

.....

.....

.....

(iii) Suggest a reagent that could be used to convert lawsone into compound **A** in the laboratory.

.....

.....

(iv) Draw the structural formula of the compound formed when lawsone is reacted with $Br_2(aq)$.

[6]

(b) Compound **A** can be oxidised to lawsone by acidified $K_2Cr_2O_7$.

(i) Use the *Data Booklet* to calculate the $E^{\ominus}_{cell}$ for this reaction.

.....

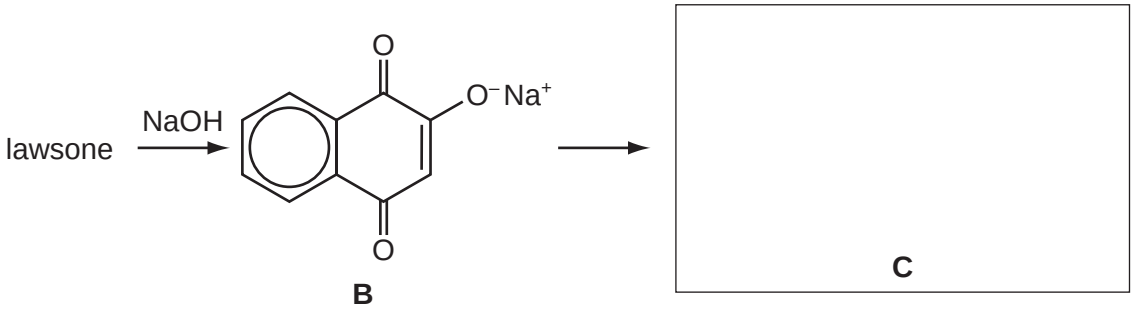
(ii) Construct an equation for this reaction. Use the molecular formulae of lawsone, $C_{10}H_6O_3$, and compound **A**, $C_{10}H_8O_3$, in your equation.

.....

(iii) When 20.0 cm^3 of a solution of compound **A** was acidified and titrated with 0.0500 mol dm^{-3} $K_2Cr_2O_7$, 7.50 cm^3 of the $K_2Cr_2O_7$ solution was needed to reach the end-point.
Calculate [**A**] in the solution.

[**A**] = ... mo dm^{-3}
[5]

(c) When lawsone is reacted with NaOH(aq), compound **B** is produced.

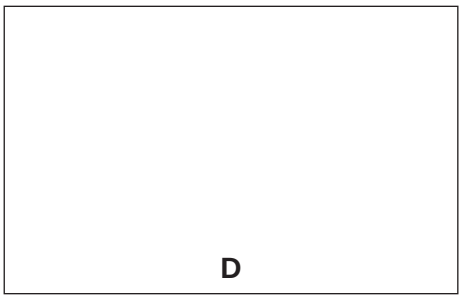


Reacting **B** with ethanoyl chloride, CH_3COCl, produces compound **C**, with the molecular formula $C_{12}H_8O_4$.

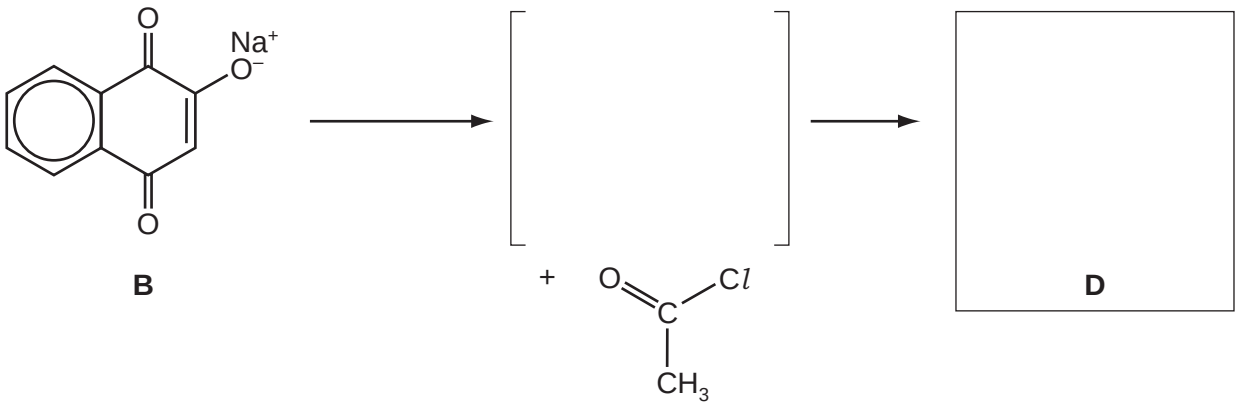
(i) Suggest the identity of compound **C**, and draw its structure in the box above.

Another compound, **D**, in addition to **C**, is produced in the above reaction. **D** is an isomer of **C** which contains the same functional groups as **C**, but in different positions.

(ii) Suggest a possible structure for **D**.



(iii) Suggest a mechanism for the formation of **D** from **B** and ethanoyl chloride by drawing relevant structures and curly arrows in the following scheme.



[3]

[Total: 14]

3 Many organic compounds, including alcohols, carbonyl compounds, carboxylic acids and esters, contain oxygen.

(a) The table below lists some oxygen-containing organic compounds and some common laboratory reagents.

(i) Complete the table as fully as you can.
If you think no reaction occurs, write 'no reaction' in the box for the structural formula(e).

reaction	organic compound	reagent	structural formula(e) of organic product(s)
A	$CH_3CH(OH)CH_3$	$NaBH_4$	
B	CH_3COCH_3	Tollens' reagent warm	
C	$CH_3CO_2CH(CH_3)_2$	KOH(aq) warm	
D	$(CH_3)_3COH$	$Cr_2O_7^{2-}/H^+$ heat under reflux	
E	CH_3COCH_3	$NaBH_4$	
F	$(CH_3)_3COH$	PCl_5	
G	$CH_3CH{=}CHCH_2OH$	MnO_4^-/H^+ heat under reflux	

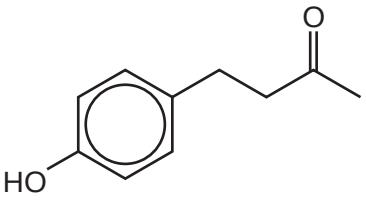
(ii) During some of the reactions in **(i)** a colour change occurs.
Complete the table below for any such reactions, stating the letter of the reaction and what the colour change is.

reaction	colour at the beginning of the reaction	colour at the end of the reaction

[12]

[Total: 12]

4 Compound **G** is a naturally occurring aromatic compound that is present in raspberries.



compound **G**

(a) Identify the functional groups present in compound **G**.

.....

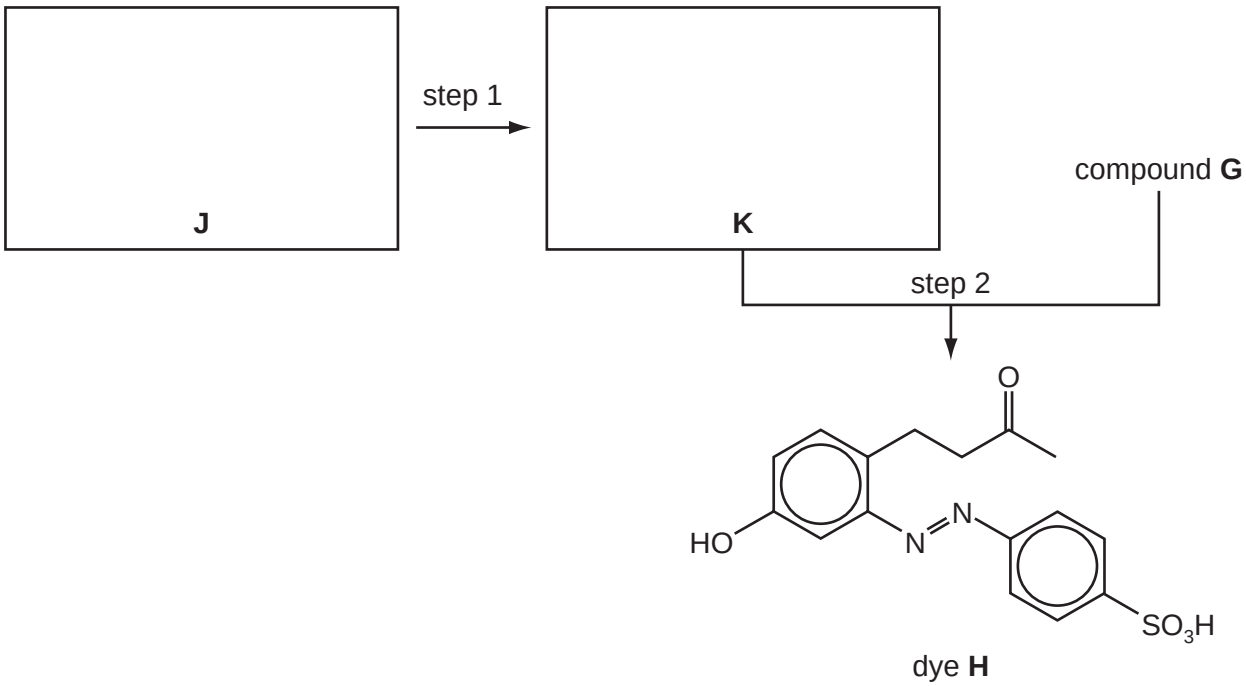
..... [2]

(b) Complete the following table with information about the reactions of the three stated reagents with compound **G**.

reagent	observation	structure of organic product	type of reaction
sodium metal			
aqueous bromine			
aqueous alkaline iodine			

[8]

(c) The dye **H** can be made from compound **G** by the route shown below.



dye **H**

(i) Draw the structures of the amine **J** and the intermediate **K** in the boxes above.

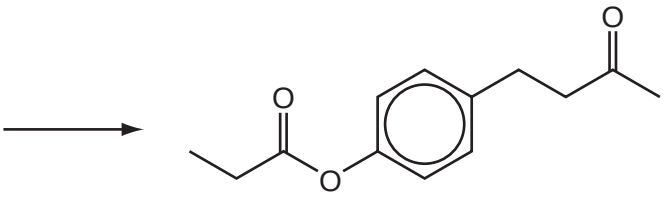
(ii) Suggest reagents and conditions for

step 1, ...

step 2. .....

[5]

(d) Suggest a reaction scheme by which compound **G** and propanoic acid could be converted into compound **L**.



compound **L**

[3]

[Total: 18]