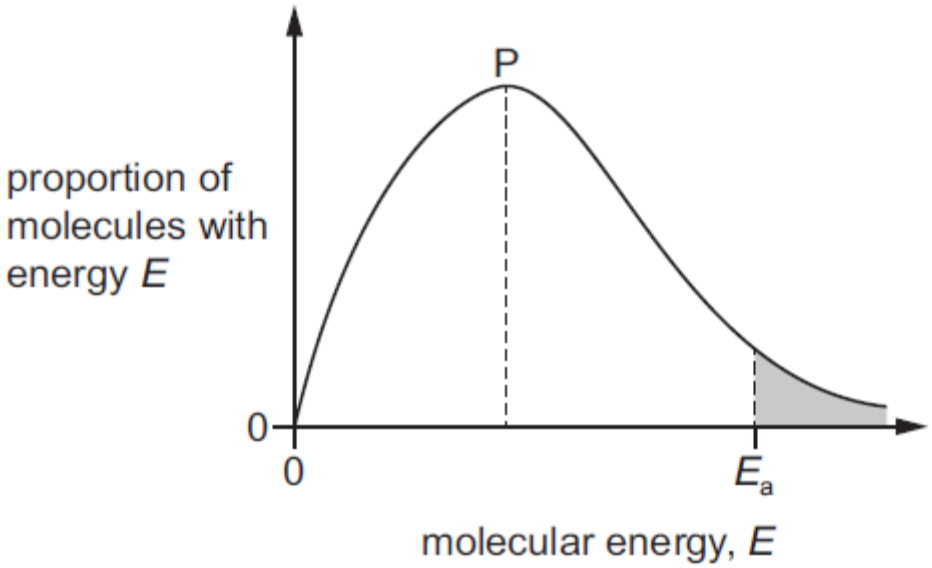
CHEMISTRY TUTORIAL 1- GRADE 13

Section A

For each question there are four possible answers, **A**, **B**, **C** and **D**. Choose the **one** you consider to be correct.
Use of the Data Booklet may be appropriate for some questions.

1. The diagram shows the Boltzmann distribution of energies in a gas. The gas undergoes a reaction with an activation energy, E_a. The peak of the distribution is labelled P.



If the same reaction is carried out in the presence of a catalyst, which statement is correct?
A The peak P is at a lower height and the position of E_a moves to the left.
B The peak P is at a lower height and the position of E_a moves to the right.
C The peak P remains at the same height and the position of E_a moves to the left.
D The peak P remains at the same height and the position of E_a moves to the right.

2. Which statement about the electrons in a ground state carbon atom is correct?
A Electrons are present in four different energy levels.
B There are more electrons in p orbitals than there are in s orbitals.
C The occupied orbital of highest energy is spherical.
D The occupied orbital of lowest energy is spherical.

3. In this question you should assume the vapour behaves as an ideal gas.
0.175 g of a volatile liquid produces a vapour of volume 4.50×10^{-5} m^3 at 100 °C and pressure of 1.013×10^5 Pa.
What is the M_r of the liquid?
A 31.9 **B** 87.1 **C** 119 **D** 127

4. Which molecule or ion contains the smallest bond angle?
A C_2H_4 **B** CH_3COCH_3 **C** NH_4^+ **D** NH_3

5. Four compounds are shown.

C_2H_4 C_2H_5OH CH_3CHO CH_3CO_2H

How many of these compounds have an odd number of σ bonds?
A 1 **B** 2 **C** 3 **D** 4

6. Ethanal, CH_3CHO, ethanol, C_2H_5OH, and methoxymethane, CH_3OCH_3, are three organic compounds.
Which compound has the highest boiling point and what is the interaction that causes this boiling point to be the highest?

	highest boiling point	interaction
A	methoxymethane	permanent dipole-dipole forces
B	ethanal	hydrogen bonds
C	ethanol	hydrogen bonds
D	ethanal	permanent dipole-dipole forces

7. Diamond is a pure form of carbon. The mass of a diamond can be measured in carats. One carat is 0.200 g of carbon.
Which expression gives the number of carats that contain 6.02×10^{23} carbon atoms?

A 0.200×12.0

B $\frac{0.200}{12.0}$

C $\frac{12.0}{0.200}$

D $\frac{0.200}{6.02 \times 10^{23}} \times 12.0$

8. The following data are needed for this question.

$$\Delta H_f^{\ominus}(N_2H_4(l)) = 50.6\,kJ\,mol^{-1}$$

$$\Delta H_f^{\ominus}(N_2O_4(g)) = 9.2\,kJ\,mol^{-1}$$

$$\Delta H_f^{\ominus}(H_2O(g)) = -241.8\,kJ\,mol^{-1}$$

Hydrazine, $N_2H_4(l)$, reacts with dinitrogen tetraoxide, $N_2O_4(g)$, to form nitrogen gas and water vapour.

$$2N_2H_4(l) + N_2O_4(g) \rightarrow 3N_2(g) + 4H_2O(g)$$

What is the enthalpy change for this reaction?
A –1077.6 kJ mol^{-1}
B –856.8 kJ mol^{-1}
C –301.6 kJ mol^{-1}
D –182.0 kJ mol^{-1}

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9. The reaction between sulfur dioxide and oxygen is reversible.

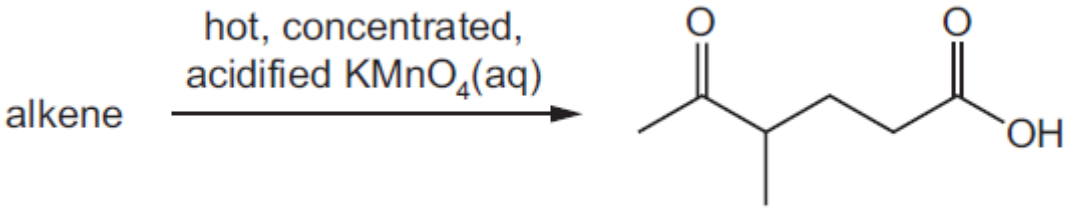
$$2SO_2(g) + O_2(g) \rightleftharpoons 2SO_3(g) \qquad K_c = 280\,mol^{-1}\,dm^3 \text{ at } 1000\,K$$

In an equilibrium mixture at 1000 K the sulfur dioxide concentration is 0.200 mol dm^{-3} and the oxygen concentration is 0.100 mol dm^{-3}.
What is the sulfur trioxide concentration?

A 1.058 mol dm^{-3}
B 1.120 mol dm^{-3}
C 2.366 mol dm^{-3}
D 5.600 mol dm^{-3}

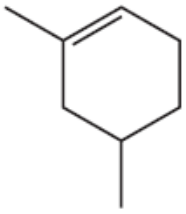
10. Alkanes are saturated hydrocarbons.
Which type of reaction are alkanes most likely to undergo?
A electrophilic addition
B electrophilic substitution
C free radical substitution
D nucleophilic addition

11. An alkene reacts with hot, concentrated, acidified potassium manganate(VII) to produce a single organic product as shown.

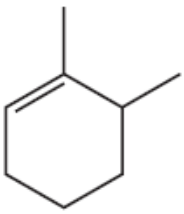


What is the structure of the alkene?

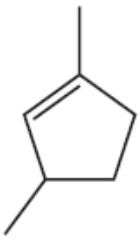
A



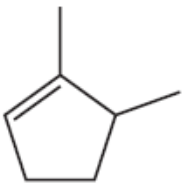
B



C



D



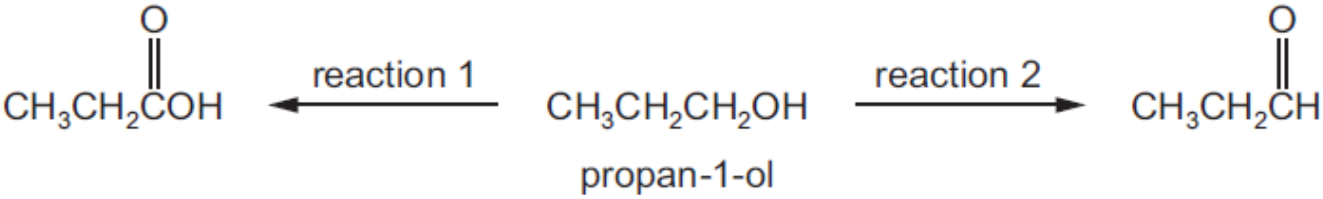
12. Alcohol X is oxidised to form compound Y.
The composition of Y is 54.54% carbon, 36.36% oxygen and 9.10% hydrogen.
The M_r of Y is 88.0.
What could be the structure of alcohol X?
A $CH_3CH_2CH(OH)CH_3$
B $CH_3CH_2CH_2CH_2CH_2OH$
C $CH_3CH_2CH_2CH_2OH$
D $CH_3CH_2CH(OH)CH_2CH_3$

13. Compound Q shows the following reactions.
- It gives an orange precipitate with 2,4-dinitrophenylhydrazine.
- It gives a red-brown precipitate with Fehling's reagent.
- It gives a pale yellow precipitate with alkaline aqueous iodine.

What could be the identity of Q?
A ethanal
B propan-2-ol
C propanal
D propanone

14. What is the smallest amount of oxygen molecules needed for the complete combustion of 40.0 g of methanol?
A 1.88 moles
B 2.50 moles
C 3.75 moles
D 5.00 moles

15. Propan-1-ol can be reacted with acidified potassium dichromate(VI) to form propanoic acid, reaction 1, or propanal, reaction 2.



How can the reaction be carried out to ensure that reaction 2 occurs rather than reaction 1?
A An excess of acidified potassium dichromate(VI) is used.
B An excess of concentrated sulfuric acid is added.
C The reaction mixture is distilled immediately after mixing.
D The reaction mixture is heated under reflux.

Section B

For each of the questions in this section, one or more of the three numbered statements **1** to **3** may be correct.
Decide whether each of the statements is or is not correct (you may find it helpful to put a tick against the statements that you consider to be correct).
The responses **A** to **D** should be selected on the basis of

A	B	C	D
1, **2** and **3** are correct	**1** and **2** only are correct	**2** and **3** only are correct	**1** only is correct

No other combination of statements is used as a correct response.
Use of the Data Booklet may be appropriate for some questions.

16. Which gaseous molecules are polar?
1 ammonia
2 hydrogen sulfide
3 boron trifluoride

17. A carbon monoxide molecule, CO, has three bonds between the carbon atom and the oxygen atom.
Which features are present in one CO molecule?
1 two lone pairs of electrons
2 a co-ordinate (dative covalent) bond from oxygen to carbon
3 two π bonds

18. Carbon can exist as allotropes which include graphite, diamond and a fullerene.
Which statements are correct?
1 All three allotropes contain covalent bonds.
2 All three allotropes are giant molecular.
3 All three allotropes have delocalised electrons.

19. Bromoethane undergoes nucleophilic substitution reactions.
Which statements are correct?
1 Bromoethane reacts with aqueous NaOH to make ethanol.
2 Bromoethane reacts with ethanolic NH_3 to make ethylamine.
3 Bromoethane reacts with ethanolic KCN to make ethanenitrile

20. Which reagents, when used in excess, can convert Y into Z?

$$\underset{\text{Y}}{CH_3CH(OH)CO_2H} \rightarrow \underset{\text{Z}}{CH_3CH(OH)CO_2Na}$$

1 Na
2 Na_2CO_3
3 NaOH

Section C

1 Ammonia, NH_3, is manufactured from nitrogen and hydrogen by the Haber process.

$$N_2(g) + 3H_2(g) \rightleftharpoons 2NH_3(g) \qquad \Delta H = -92\,kJ\,mol^{-1}$$

(a) Some bond energies are given.
N≡N = 944 kJ mol^{-1}
H–H = 436 kJ mol^{-1}

(i) Explain the meaning of the term *bond energy*.

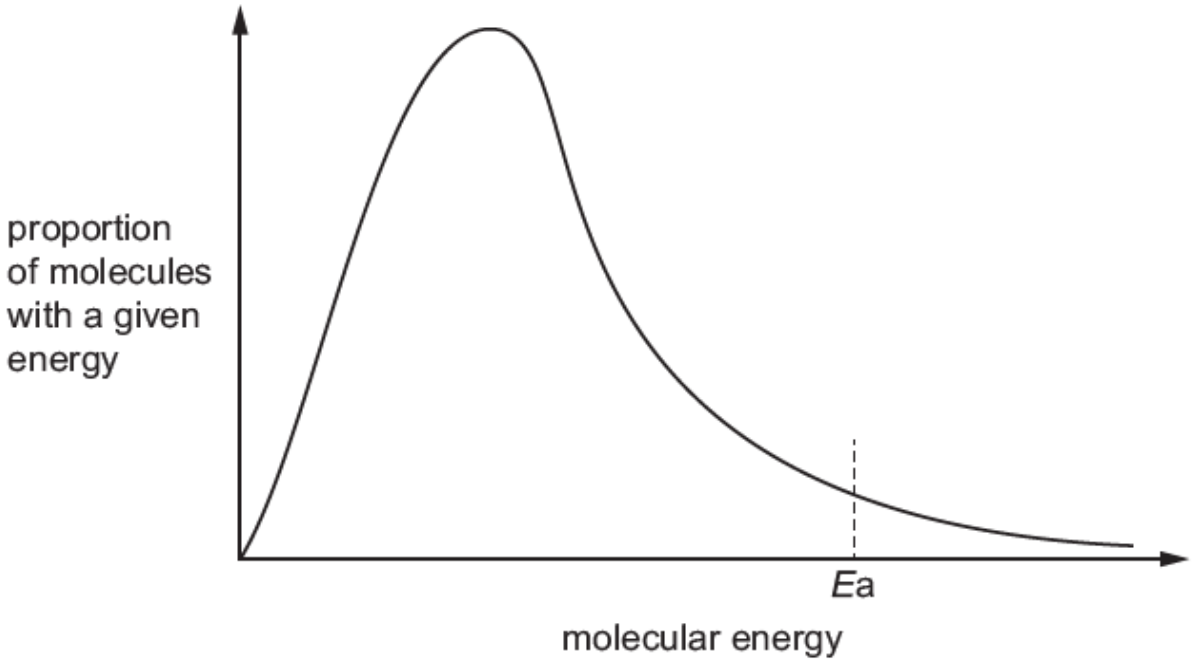
.....

.....

(ii) Use the data to calculate a value for the N–H bond energy.
You must show your working.

N–H bond energy = ... kJ mol^{-1}

(b) The Haber process is usually carried out at a temperature of approximately 400 °C in the presence of a catalyst. Changing the temperature affects both the rate of production of ammonia and the yield of ammonia.
The Boltzmann distribution for a mixture of nitrogen and hydrogen at 400 °C is shown.
*E*a represents the activation energy for the reaction.



(i) Using the same axes, sketch a second curve to indicate the Boltzmann distribution at a higher temperature.

(ii) With reference to the Boltzmann distribution, state and explain the effect of increasing temperature on the rate of production of ammonia.

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(iii) State and explain the effect of increasing temperature on the yield of ammonia.
Use Le Chatelier's principle to explain your answer.

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(c) At a pressure of 2.00 × 107 Pa, 1.00 mol of nitrogen, $N_2(g)$, was mixed with 3.00 mol of hydrogen, $H_2(g)$. The final equilibrium mixture formed contained 0.300 mol of ammonia, $NH_3(g)$.

(i) Calculate the amounts, in mol, of $N_2(g)$ and $H_2(g)$ in the equilibrium mixture.

$N_2(g)$ = ... mol

$H_2(g)$ = ... mol

(ii) Calculate the partial pressure of ammonia, pNH_3, in the equilibrium mixture.
Give your answer to **three** significant figures.

pNH_3 = ... Pa

(d) In another equilibrium mixture the partial pressures are as shown.

substance	partial pressure / Pa
$N_2(g)$	2.20×10^6
$H_2(g)$	9.62×10^5
$NH_3(g)$	1.40×10^4

(i) Write the expression for the equilibrium constant, *K*p, for the production of ammonia from nitrogen and hydrogen.

(ii) Calculate the value of *K*p for this reaction.
State the units.

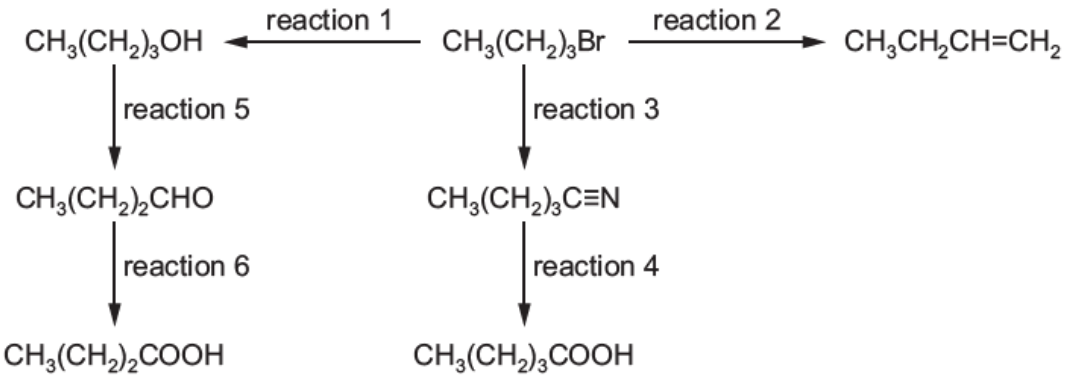
*K*p = ... units = ...

(iii) This reaction is repeated with the same starting amounts of nitrogen and hydrogen.
The same temperature is used but the container has a smaller volume.
State the effects, if any, of this change on the yield of ammonia and on the value of *K*p.

effect on yield of ammonia .....

effect on value of *K*p .....

2. Some reactions based on 1-bromobutane, $CH_3(CH_2)_3Br$, are shown.

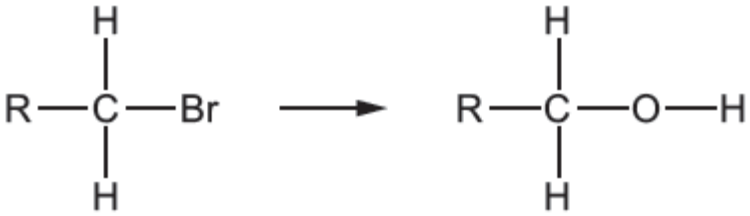


(a) For each of the reactions state the reagent(s), the particular conditions required, if any, and the type of reaction.
For the type of reaction choose from the list.
Each type may be used once, more than once or not at all.
Each reaction may be described by more than one type.

elimination hydrolysis substitution
oxidation condensation addition

reaction	reagent(s) and conditions	type(s) of reaction
1		
2		
3		
4		
5		
6		

(b) Complete the diagram to show the S_N2 mechanism of reaction 1. R represents the $CH_3(CH_2)_2$ group.
Include all necessary charges, dipoles, lone pairs and curly arrows.



(c) 2-bromo-2-methylpropane is a tertiary halogenoalkane that is a structural isomer of 1-bromobutane.

(i) Define the term *structural isomer* and name the three different types of structural isomerism.

definition .....

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types of structural isomerism

1 .....

2 .....

3 .....

(ii) 2-bromo-2-methylpropane is treated with the same reagents as in reaction 1.
Methylpropan-2-ol is formed.
Identify the mechanism for this reaction.
Explain why this reaction proceeds via a different mechanism from that of reaction 1.

mechanism .....

explanation .....

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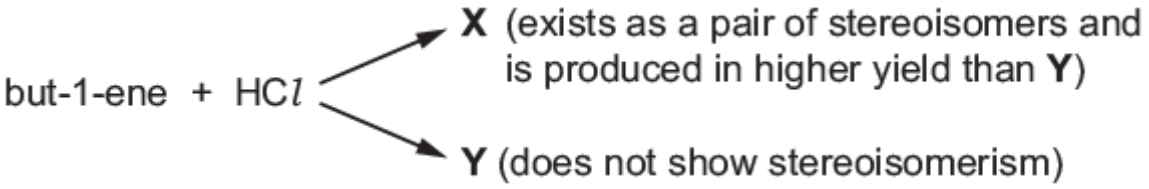
(d) The product of reaction 2, but-1-ene, does **not** show stereoisomerism. However, but-1-ene reacts with HC*l* to form a mixture of structural isomers **X** and **Y**.



(i) Explain the meaning of the term *stereoisomers*.

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(ii) Give **two** reasons why but-1-ene does **not** show stereoisomerism.

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(iii) Name **X** and **Y**.

X .....

Y .....

(iv) Name the type of stereoisomerism shown by **X**.

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(v) Use the conventional representation to draw the two stereoisomers of **X**.

3. For many compounds the enthalpy change of formation cannot be calculated directly. An indirect method based on enthalpy changes of combustion can be used.
The enthalpy change of combustion can be found by a calorimetry experiment in which the heat energy given off during combustion is used to heat a known mass of water and the temperature change recorded.

(a) (i) Explain the meaning of the term *standard enthalpy change of combustion*.

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(ii) Write the equation for the complete combustion of ethanol, C_2H_5OH.

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(b) In an experiment to determine the enthalpy change of combustion of ethanol, 0.23 g of ethanol was burned and the heat given off raised the temperature of 100 g of water by 16.3 °C.
(i) Calculate the heat energy change, *q*, during the combustion of 0.23 g of ethanol.

q = ... J

(ii) Calculate the enthalpy change on burning 1 mole of ethanol. Include a sign in your answer.

ΔH = ... kJ mol^{-1}

(iii) Suggest **two** reasons why the value for the enthalpy change of combustion of ethanol determined by a simple laboratory calorimetry experiment is likely to be lower than the true value.

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(c) The table gives some enthalpy change of combustion values.

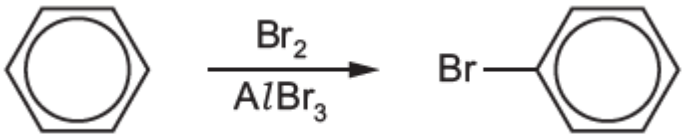
substance	enthalpy change of combustion / kJ mol^{-1}
C(s)	–393.5
$H_2(g)$	–285.8
$C_3H_7OH(l)$	–2021.0

(i) Construct a labelled energy cycle to show how these values could be used to calculate the enthalpy change of formation of $C_3H_7OH(l)$, ΔH_f.

(ii) Calculate the enthalpy change of formation, ΔH_f, of $C_3H_7OH(l)$.

ΔH_f = ... kJ mol^{-1}

4 (a) Bromobenzene can be prepared from benzene as shown.



(i) Name the mechanism of this reaction.

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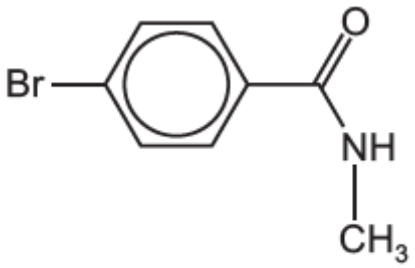
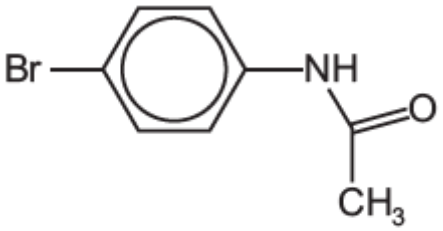
(ii) Draw the mechanism of this reaction. Include all relevant curly arrows, any dipoles and charges.



V



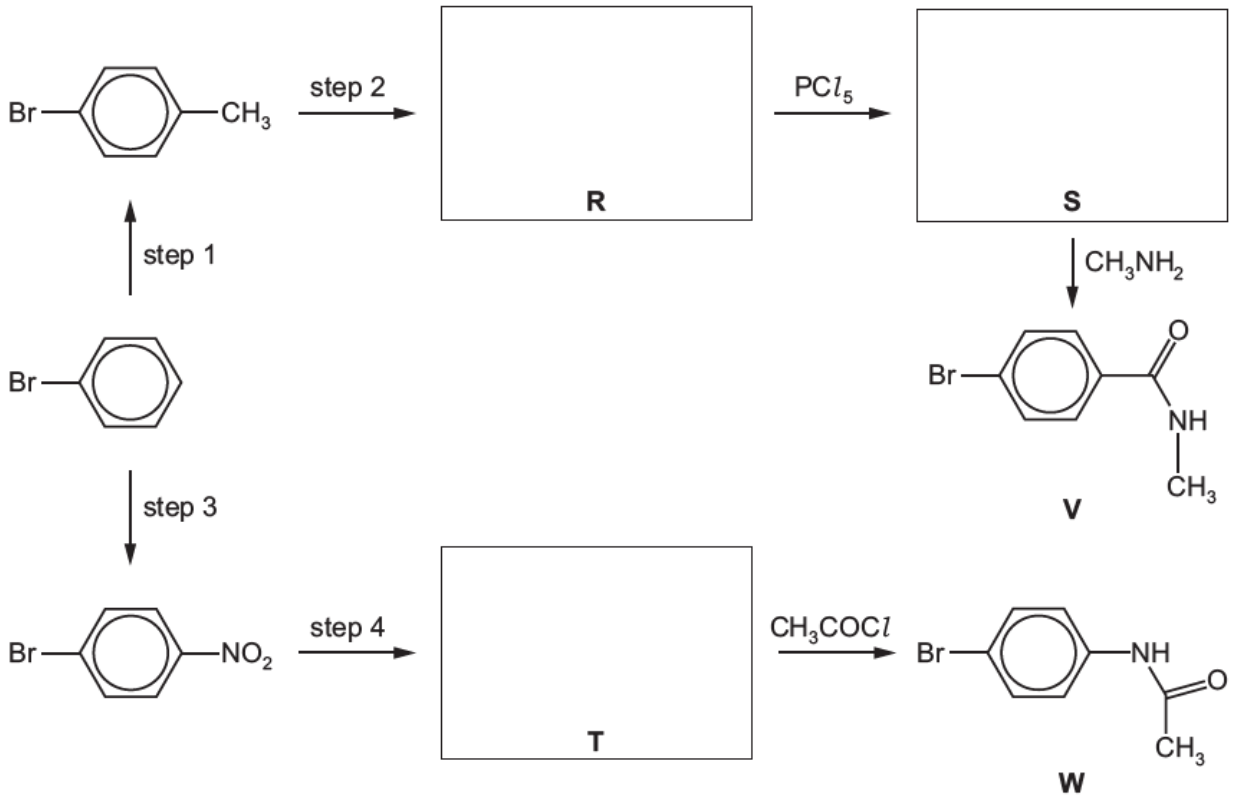
W

(b) Two isomeric aromatic compounds, **V** and **W**, each contain three functional groups, two of which are shown in the table.

Complete the table with the **other** functional groups present in **V** and **W**.

substance	functional groups present		
V	bromo group	aryl (benzene) group	.....
W	bromo group	aryl (benzene) group	.....

(c) Compounds **V** and **W** can be synthesised from bromobenzene by the following routes.



(i) Suggest reagents for each of the steps 1– 4.

step 1 .....

step 2 .....

step 3 .....

step 4 .....

(ii) Deduce structures for **R**, **S** and **T** and draw their structural formulae in the boxes.

(d) (i) Draw the structures of the two organic products from the reaction of **V** and **W** with $LiAlH_4$.

product from **V**

product from **W**

(ii) Name the *type of reaction* occurring between LiA*l* H_4 and **V** or **W**.

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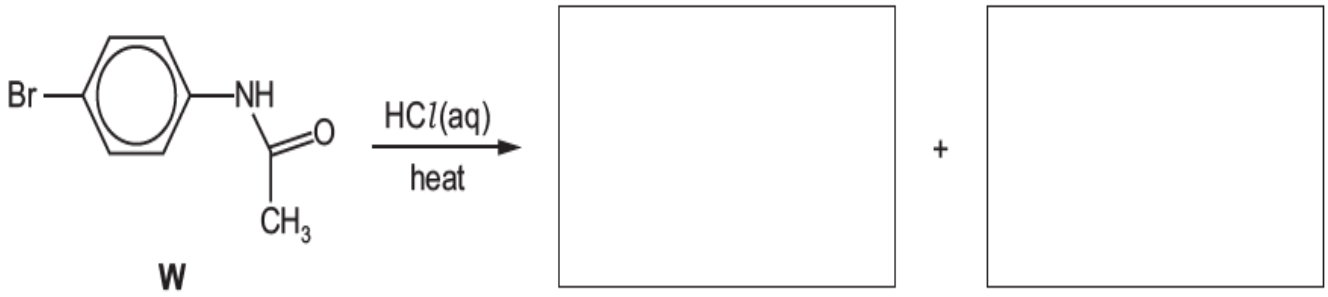
(e) **V** and **W** can be hydrolysed using hot HC*l* (aq).
(i) Draw the structures of the two organic products of the hydrolysis of **W**.



W

(ii) The products formed from the hydrolysis of **W** are soluble in aqueous acid, whereas a precipitate, **X**, is formed on hydrolysing **V**.
Draw the structure of compound **X**.

(iii) Suggest why **X** is insoluble in water.

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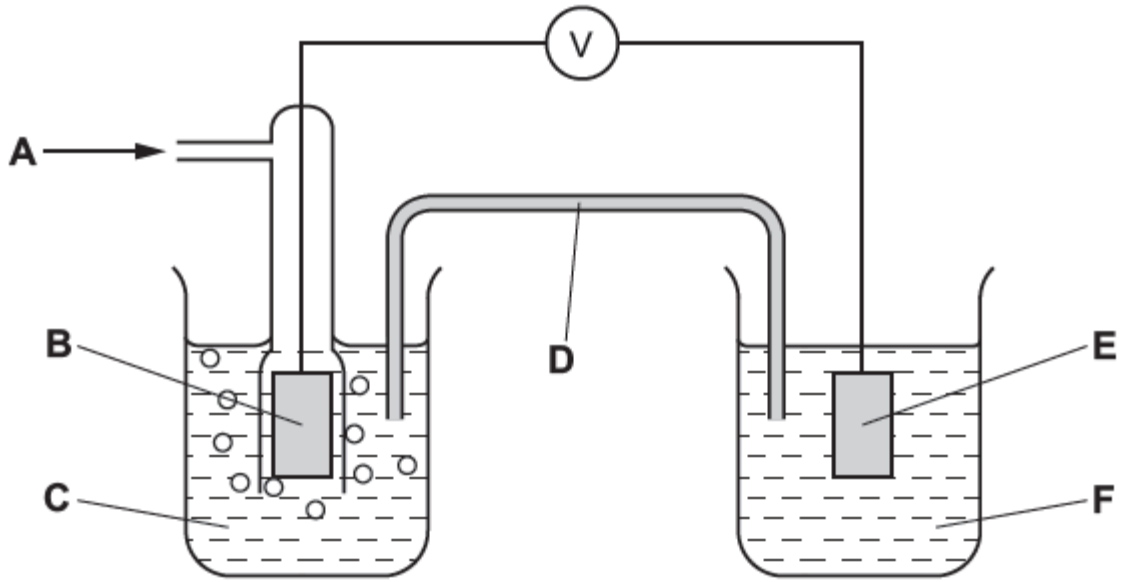
5 (a) The diagram shows the apparatus used to measure the standard electrode potential, E^{o}, of $Fe^{3+}(aq) / Fe^{2+}(aq)$.



A ..... **D** .....

B ..... **E** .....

C ..... **F** .....

(ii) Label the diagram to show
- which is the positive electrode,
- the direction of electron flow in the external circuit.

Use the *Data Booklet* to help you.

(b) In another experiment, an $Fe^{3+}(aq) / Fe^{2+}(aq)$ half-cell was connected to a $Cu^{2+}(aq) / Cu(s)$ half-cell.
Determine the standard cell potential, , when these two half-cells are connected by a wire and the circuit is completed.
Use the *Data Booklet* to help you.

(c) (i) The E^{o} of $Ni^{2+}(aq) / Ni(s)$ is –0.25 V.
State and explain how the electrode potential changes if the concentration of $Ni^{2+}(aq)$ is decreased.

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(ii) The E^{o} of $Cr^{3+}(aq) / Cr^{2+}(aq)$ is –0.41 V.
Calculate the electrode potential when $[Cr^{3+}(aq)]$ is 0.60 mol dm^{-3} and $[Cr^{2+}(aq)]$ is 0.15 mol dm^{-3}. Use the Nernst equation.

6 (a) Chlorine dioxide undergoes the following reaction in aqueous solution.

$$2ClO_2 + 2OH^- \rightarrow ClO_2^- + ClO_3^- + H_2O$$

The initial rate of the reaction was measured at different initial concentrations of ClO_2 and OH^-. The table shows the results obtained.

experiment	$[ClO_2]$ / mol dm^{-3}	$[OH^-]$ / mol dm^{-3}	initial rate / mol dm^{-3} s^{-1}
1	1.25×10^{-2}	1.30×10^{-3}	2.33×10^{-4}
2	2.50×10^{-2}	1.30×10^{-3}	9.34×10^{-4}
3	2.50×10^{-2}	2.60×10^{-3}	1.87×10^{-3}

(i) Use the data in the table to determine the rate equation, showing the order with respect to each reactant. Show your reasoning.

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(ii) Calculate the value of the rate constant, *k*, using the data from experiment 2. State its units.

k = ... units .....

(b) (i) Explain the difference between heterogeneous and homogeneous catalysts.

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(ii) Complete the table using ticks to indicate whether the catalyst used in the reaction is heterogeneous or homogeneous.

catalysed reaction	heterogeneous	homogeneous
manufacture of ammonia in the Haber process		
removal of nitrogen oxides from car exhausts		
oxidation of sulfur dioxide in the atmosphere		

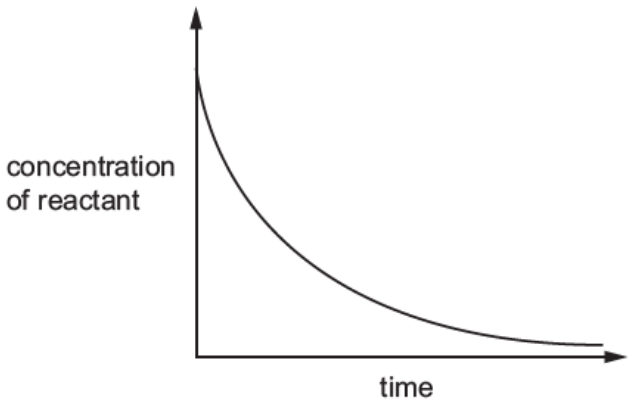
(c) Some reactions are catalysed by one of the products of the reaction. This is called autocatalysis. An example of autocatalysis is the reaction between acidified manganate(VII) ions, MnO_4^-, and ethanedioic acid, $(CO_2H)_2$. Mn^{2+} ions catalyse this reaction. The reaction is slow in the absence of a catalyst.

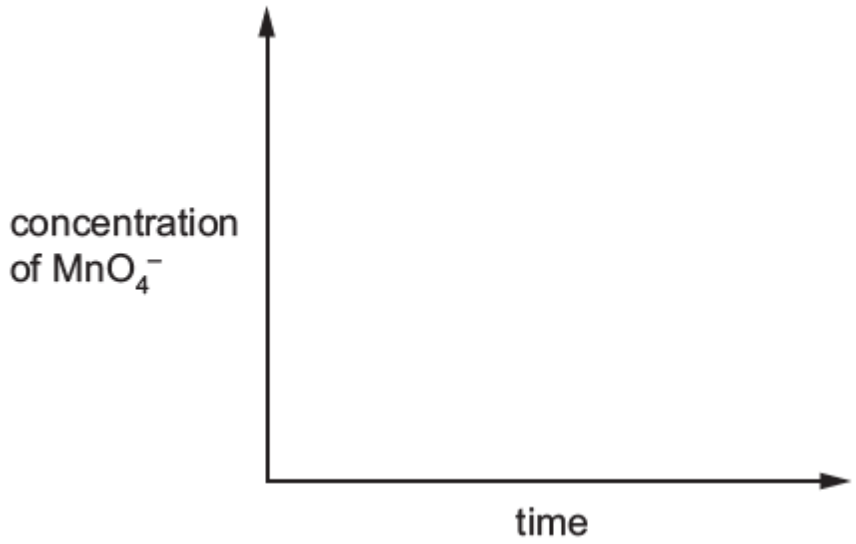
(i) Balance the equation for this reaction.

$$.....MnO_4^- + ...H^+ + ...(CO_2H)_2 \longrightarrow .....Mn^{2+} + ...CO_2 + ...H_2O$$

(ii) The graph shown is a concentration-time graph for a typical reaction.

On the axes below, sketch the curve you would expect for the autocatalysed reaction in **(i)**.





(d) (i) Describe, with the aid of a reaction pathway diagram, the effect of a catalyst on a reversible reaction. Suggest why catalysts are used in industrial processes.

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(ii) The reaction for the Haber process to produce ammonia is shown.

$$N_2(g) + 3H_2(g) \rightleftharpoons 2NH_3(g) \qquad \Delta H = -92\,kJ\,mol^{-1}$$

At 500 °C, when pressure is measured in atmospheres, the numerical value of *K*p for this equilibrium is 1.45×10^{-5}.

- Write the expression for *K*p for this equilibrium.

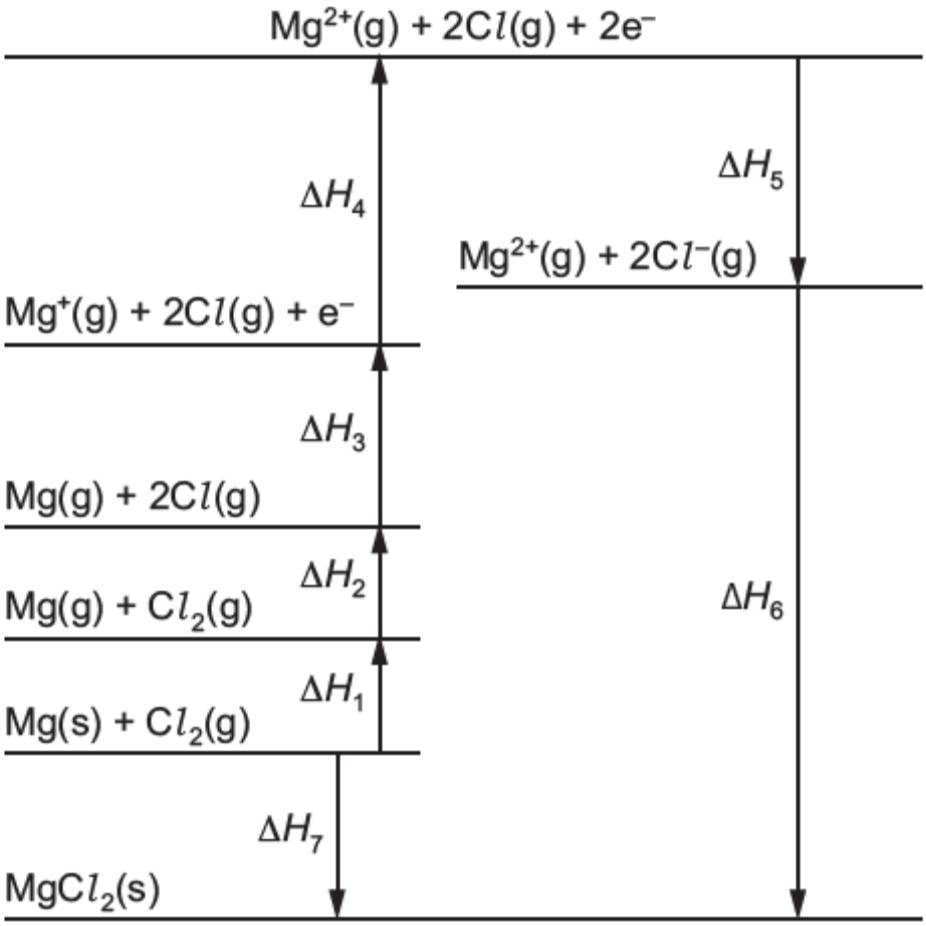
- Calculate the partial pressure of NH3 at equilibrium at 500 °C, when the partial pressure of N_2 is 20 atm and that of H_2 is 60 atm.

pNH_3 = ... atm

7 (a) Complete the table using ticks to indicate whether the sign of each type of energy change, under standard conditions, is always positive, always negative or could be either positive or negative.

energy change	always positive	always negative	either positive or negative
electron affinity			
enthalpy change of atomisation			
ionisation energy			
lattice energy			

(b) The Born-Haber cycle for magnesium chloride is shown.



(i) Explain why ΔH_4 is greater than ΔH_3.

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(ii) What names are given to the enthalpy changes ΔH_6 and ΔH_7?

ΔH_6 .....

ΔH_7 .....

(c) Chlorine is in Group 17.
Suggest the trend in the first electron affinity of the elements in Group 17. Explain your answer.

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(d) The equation for the formation of magnesium oxide from its elements is shown.

$$Mg(s) + \tfrac{1}{2}O_2(g) \rightarrow MgO(s) \qquad \Delta H^{\ominus} = -602\,kJ\,mol^{-1}$$

substance	$S^{\ominus}/J\,K^{-1}\,mol^{-1}$
Mg(s)	32.7
$O_2(g)$	205
MgO(s)	26.9

Use the equation and the data given in the table to calculate ΔG^{o} for the reaction at 25 °C.

ΔG^{o} = ... units .....