GCE A LEVEL CHEMISTRY

S21-A410

Assessment Resource I

Physical and Inorganic Chemistry

1. *(a)* Draw a dot and cross diagram for the molecule BF_3. [1]

(b) Use valence shell electron pair repulsion theory to explain why BF_3 has a trigonal planar structure. [1]

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2. Addition of excess potassium iodide to 25.0 cm^3 of aqueous copper(II) sulfate produces a brown solution of iodine and a white solid.

(a) Give the **formula** of the white solid. [1]

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(b) The iodine is titrated using sodium thiosulfate solution of concentration 0.200 mol dm^{-3}.

$$2S_2O_3^{2-} + I_2 \longrightarrow 2I^- + S_4O_6^{2-}$$

The experiment is repeated and the results are shown below.

	Titration 1	Titration 2	Titration 3	Titration 4	Mean titre
Volume of sodium thiosulfate solution / cm^3	24.40	23.90	23.80	23.85	23.85

(i) Suggest why the value from titration 1 is not used in calculating the mean titre. [1]

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(ii) Calculate the number of moles of iodine produced from each 25.0 cm^3 of aqueous copper(II) sulfate solution. [1]

Moles of iodine = ... mol

3. Iron metal reacts with chlorine to form iron(III) chloride and it reacts with iodine to form iron(II) iodide. Use the standard electrode potentials below to explain this difference. [2]

	Standard electrode potential, E^{θ}/V
$Cl_2(aq) + 2e^- \rightleftharpoons 2Cl^-(aq)$	+1.36
$Fe^{3+}(aq) + e^- \rightleftharpoons Fe^{2+}(aq)$	+0.77
$I_2(aq) + 2e^- \rightleftharpoons 2I^-(aq)$	+0.54

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4. Organometallic compounds contain metal atoms bonded directly to the carbon atom of an organic group. One example is methyllithium (CH_3Li).

(a) The electronegativity values of the elements present in methyllithium are given below.

Element	H	Li	C
Electronegativity	2.20	0.98	2.55

(i) State what is meant by the term *electronegativity*. [1]

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(ii) State which type of bond will form between lithium and carbon. Give a reason for your answer. [1]

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(b) Methyllithium is synthesised by treating bromomethane with a suspension of metallic lithium in a non-aqueous solvent. This forms a solution of methyllithium in the non-aqueous solvent.

$$CH_3Br + 2Li \longrightarrow CH_3Li + LiBr$$

(i) Calculate the atom economy for this method of producing methyllithium. [2]

Atom economy = ... %

(ii) An alternative method of synthesising methyllithium is by using chloromethane as a source of the methyl group. Use the information given below to suggest which method is better for the production of methyllithium.

You should include **two** advantages and **one** disadvantage for your chosen method. [4]

	CH_3Cl	CH_3Br	CH_3Li	LiCl	LiBr
M_r	50.5	94.9	21.9	42.4	86.8
Melting temperature / °C	–97	–94			
Boiling temperature / °C	–24	+4			
Solubility in solvent used	very soluble	very soluble	soluble	insoluble	partly soluble
Relative cost per gram	1.5	1.0			

Atom economy for production of methyllithium from chloromethane = 34.0 %

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(c) Methyllithium is a very strong base.

State what is meant by the term *strong base*. [1]

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(d) When methyllithium is added to water the reaction below occurs.

$$CH_3Li(sol) + H_2O(l) \longrightarrow LiOH(aq) + CH_4(g)$$

When 10.00 cm^3 of a non-aqueous solution of methyllithium is added to 250.0 cm^3 of water a total volume of 391.8 cm^3 of methane is produced at a temperature of 298 K and a pressure of 1 atm. The pH of the aqueous layer formed is 12.8.

You may assume that LiOH is totally insoluble in the non-aqueous solvent.

(i) Use the volume of gas produced to calculate the concentration of the initial methyllithium solution. Give your answer to an **appropriate** number of significant figures.

You **must** show your working. [3]

Concentration = ... $mol\,dm^{-3}$

(ii) Use the pH to calculate the concentration of the initial methyllithium solution.

You **must** show your working. [3]

Concentration = ... $mol\,dm^{-3}$

(iii) State which of these two methods gives the more accurate value. Give a reason for your answer. [2]

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(iv) The reaction between methyllithium and water is exothermic. The enthalpy change of the reaction is $-198\,kJ\,mol^{-1}$.

Calculate the expected temperature rise when 0.010 mol of pure methyllithium is added to $250.0\,cm^3$ of water. [3]

Temperature rise = ... °C

5. The oxidation of carbon monoxide to carbon dioxide in the presence of suitable catalysts is an important method of removing this toxic gas from gas mixtures produced during incomplete combustion.

$$2CO + O_2 \longrightarrow 2CO_2$$

Some catalysts for this reaction are produced by soaking aluminium oxide pellets in a solution of a transition metal chloride followed by drying. Two suitable transition metal chlorides are palladium chloride and ruthenium chloride.

(a) These catalysts are examples of heterogeneous catalysts.

(i) State what is meant by *heterogeneous* in this context. [1]

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(ii) Give another example of a heterogeneous catalyst, clearly identifying the reaction that it catalyses. [1]

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(b) Some information regarding these catalysed reactions is given below.

	Activation energy / $kJ\,mol^{-1}$	Frequency factor, A / $mol\,dm^{-3}\,s^{-1}$
palladium catalyst	61.7	6.1×10^9
ruthenium catalyst	79.4	14.1×10^9

(i) At a temperature of 600 K, the value of the rate constant for the reaction catalysed by palladium is 2.58×10^4.

I. Give the unit for this rate constant. [1]

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II. Find the value of the rate constant for the ruthenium catalyst under the same conditions and hence identify which of these two catalysts is the more effective. [4]

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(ii) Under certain conditions the oxidation of carbon monoxide can occur without a catalyst. The rate equation for this process is

$$\text{rate} = k[CO][O_2]$$

Suggest a two-step mechanism for the uncatalysed oxidation of carbon monoxide. Label the rate determining step clearly. [3]

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(c) Carbon monoxide is classed as a reducing agent.

(i) State what is meant by a *reducing agent*. [1]

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(ii) Explain why carbon monoxide is a reducing agent whilst the corresponding oxide of lead, PbO, is not. [2]

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