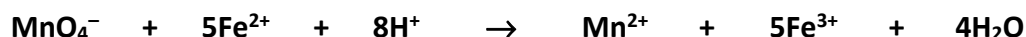


Section A

Answer at least two questions from this section. See page 1 for full instructions.

1. A solution of $(\text{NH}_4)_2\text{SO}_4 \cdot \text{FeSO}_4 \cdot 6\text{H}_2\text{O}$ (hydrated ammonium iron(II) sulfate), used as a primary standard, was prepared by dissolving 8.82 g of the crystals in dilute sulfuric acid and making the solution up to exactly 250 cm^3 with deionised water. This standard solution was titrated in 25.0 cm^3 portions, to which some more dilute sulfuric acid had been added, with a solution of potassium manganate(VII) (KMnO_4). On average, 20.45 cm^3 of the potassium manganate(VII) solution were required for complete oxidation of the Fe^{2+} ions.

The equation for the titration reaction is:



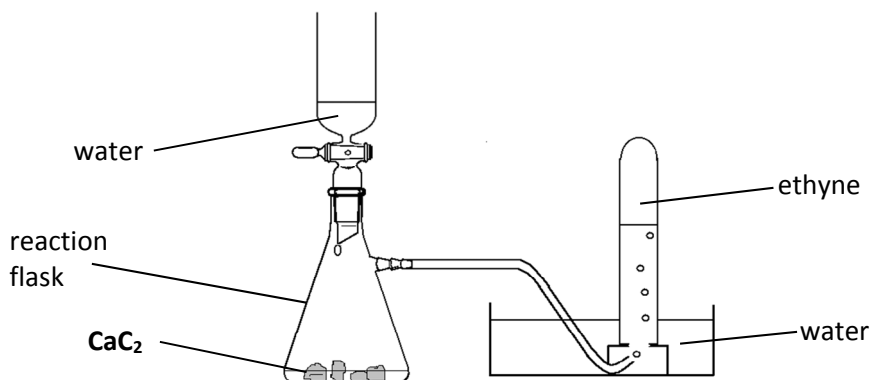
- (a) (i) Explain the underlined term.
(ii) Give two essential properties of a primary standard for volumetric analysis. (11)
- (b) Explain why it was necessary
(i) to use dilute sulfuric acid when preparing the standard solution from hydrated ammonium iron(II) sulfate,
(ii) to add more dilute sulfuric acid to each 25.0 cm^3 portion of the standard solution used in the titrations. (9)
- (c) Describe fully the procedure used *during the titrations* to ensure the accuracy of the end point.
What observation indicates that the correct end point has been reached? (15)
- (d) Calculate
(i) the number of moles of Fe^{2+} ion in a 25.0 cm^3 portion of the standard solution,
(ii) the number of moles of potassium manganate(VII) required to oxidise this quantity of Fe^{2+} ion,
(iii) the molarity of the potassium manganate(VII) solution. (15)

2. A student prepared ethene and ethyne gases and compared their properties.

(a) The apparatus shown was used to prepare and collect ethyne.

(i) What was observed in the reaction flask as the water was dropped onto the calcium carbide (CaC_2)?

(ii) Explain why the first few test-tubes of gas collected were discarded. (6)



(b) (i) Draw a labelled diagram of a suitable arrangement of apparatus and chemicals for the preparation and collection of ethene.

(ii) State *and* explain two safety precautions that should be taken when carrying out the experiment. (24)

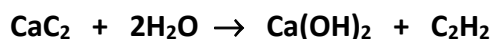
(c) Combustion tests were carried out on samples of ethene and ethyne.

(i) Compare the observations made in the two tests.

(ii) Write a balanced equation for the complete combustion of ethyne in oxygen. (9)

(d) Name a reagent used to test the gases for unsaturation. (3)

(e) The mass of calcium carbide consumed in the preparation of ethyne, in an apparatus like that shown above, was 3.2 g. The equation for the reaction is as follows:



Calculate the maximum theoretical number of ethyne molecules produced in this reaction. (8)

3. (a) Define rate of reaction. (5)

In the reaction of sodium thiosulfate solution with hydrochloric acid, according to the following balanced equation, sulfur precipitates as a fine, pale-yellow powder.



To investigate the effect of the sodium thiosulfate concentration on the rate (r) of this reaction, the time (t), taken for a certain mass of sulfur to precipitate after the reactants were mixed, was measured at room temperature for a number of different sodium thiosulfate concentrations using a constant concentration of hydrochloric acid.

The inverse of the time for each run was taken as a measure of the initial rate of reaction ($r = 1/t$). In each run a stopwatch was started as 100 cm³ of the sodium thiosulfate solution of known concentration were added to a reaction flask containing 10 cm³ of the hydrochloric acid solution.

The table contains the data collected.

			Column X			Column Y
Run	Volume stock (30 g/L) $\text{Na}_2\text{S}_2\text{O}_3$ solution (cm ³)	Volume water used for dilution (cm ³)	Concentration $\text{Na}_2\text{S}_2\text{O}_3$ (g/L)	Volume HCl (cm ³)	t (s)	r (s ⁻¹)
1	100	0	30.0	10	50	
2	80	20		10	63	
3	60	40		10	83	
4	40	60		10	125	
5	20	80		10	250	
6	0	100	0	10	-	0

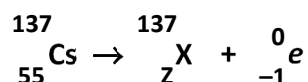
- (b) Describe a method you could use to determine when the same mass of sulfur had been formed in each run. (9)
- (c) Copy **Column X** into your answer book and fill in the missing concentrations. (6)
- (d) (i) Copy **Column Y** into your answer book and fill in the missing rates, correct to three decimal places.
(ii) Plot a graph of concentration of sodium thiosulfate (in g/L) *versus* rate (r) for runs 1 to 6.
(iii) What can you conclude from your graph? (21)
- (e) Describe how you could use the same reaction to investigate the effect of changing temperature on the reaction rate. (9)

Section B

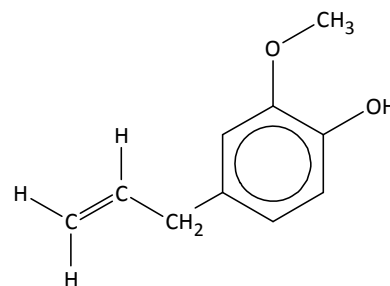
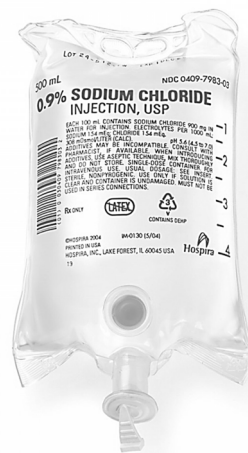
See page 1 for instructions regarding the number of questions to be answered.

4. Answer **eight** of the following (a), (b), (c), etc. (50)

- (a) Why did Mendeleev place tellurium before iodine in his periodic table of the elements?
- (b) Identify the main energy levels involved in the electron transition that gives rise to the first (red) line of the Balmer series in the emission spectrum of the hydrogen atom.
- (c) Identify the atomic symbol **X** and the atomic number **Z** of the daughter nucleus in the following nuclear equation.



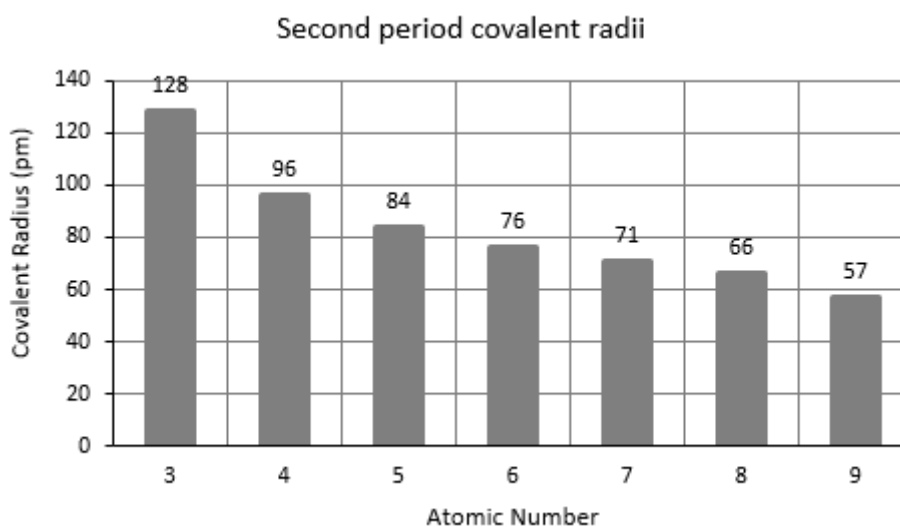
- (d) Write the oxidation number for
- (i) oxygen in **OF₂**,
- (ii) xenon in **XeF₄**.
- (e) State Avogadro's law.
- (f) Calculate the mass of sodium chloride required to prepare 500 cm³ of a 0.9% (w/v) saline solution for use as an intravenous fluid.
- (g) Identify, in ammonia, the type of
- (i) *intramolecular* bonding,
- (ii) *intermolecular* forces, present.
- (h) The structure of eugenol is shown.
- (i) Write the molecular formula of eugenol.
- (ii) Name a spectroscopic technique that could help confirm the identity of a sample of eugenol.
- (i) Write a balanced equation for the displacement reaction between copper metal and **AgNO₃** solution to produce copper(II) nitrate.
- (j) How does boiling remove any temporary hardness, caused by the presence of calcium hydrogencarbonate, in a water sample?
- (k) Answer part **A** or part **B**.
- A** Explain using balanced equations how sulfuric acid in rainwater is formed from sulfur dioxide in the atmosphere.



or

B How is aluminium anodised?

5. (a) Define an atomic orbital.
Write the ground state *s*, *p* electron configuration for a carbon atom.
How many orbitals are occupied? (12)
- (b) Why is it difficult to specify the absolute boundary of an atom?
State the definition used for the (covalent) radius of an atom. (9)
- (c) (i) Describe and account for the general trend in (covalent) radii down Group 1 of the periodic table of the elements.
- (ii) The bar chart below shows the (covalent) radii (2008 values) for the atoms of the second period of the periodic table excluding neon.
Account for the general trend shown. (9)



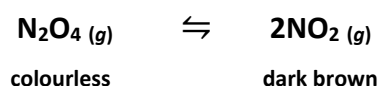
- (d) Define the first ionisation energy of an isolated atom of an element in its ground state.
Why do first ionisation energy values show a general increase across the second period of the periodic table? (12)
- (e) The full set of successive ionisation energy values for the electrons in carbon, in kJ mol^{-1} and in order starting with the first, is {1086, 2353, 4620, 6223, 37831, 47277}.
How does this set of numbers provide evidence for
- (i) the number of electrons in a carbon atom,
- (ii) the number of electrons in each main energy level in a carbon atom? (8)

6. (a) Identify the hydrocarbon gas produced by anaerobic bacterial decomposition of either animal waste or vegetation.
Give a major use of this gas.
Why is the concentration of this gas in the atmosphere a cause of concern? (11)
- (b) The boiling points of propane (C_3H_8) and dodecane ($\text{C}_{12}\text{H}_{26}$) are $-42\text{ }^\circ\text{C}$ and $216\text{ }^\circ\text{C}$ respectively. Explain why high molecular mass alkanes have high boiling points. (6)
- (c) (i) Write a balanced equation for the dehydrocyclisation reaction in which heptane is converted into methylbenzene and hydrogen.
(ii) What is the purpose of dehydrocyclisation in oil refining? (9)
- (d) But-2-ene, 2-methylbutane and a second alkene (**X**) were the products of catalytic cracking of a dodecane ($\text{C}_{12}\text{H}_{26}$) molecule.
(i) Draw a structural formula for each named product.
(ii) Deduce the molecular formula of the third product (**X**). (9)
- (e) State Hess's law.
The heats of formation of dodecane, but-2-ene, 2-methylbutane and **X** are -350.9 , -9.3 , -178.4 and 20.0 kJ mol^{-1} respectively.
Use the data to calculate the heat change for the cracking reaction:



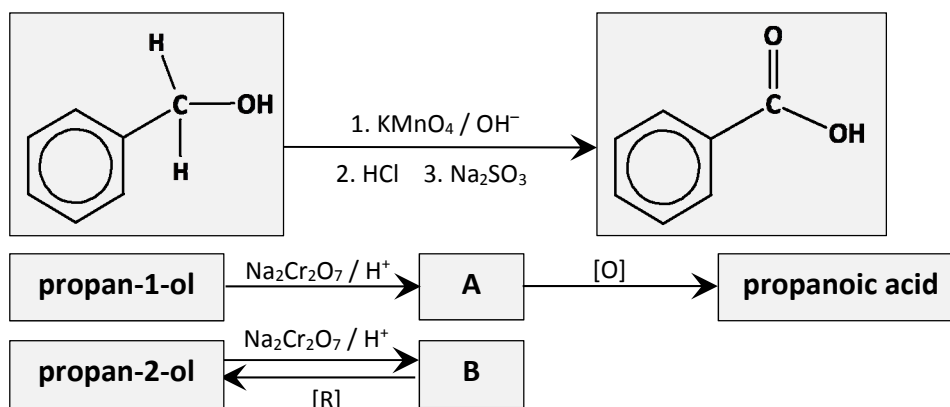
7. (a) What is meant by a chemical equilibrium?
Why is it described as a dynamic state?
State Le Châtelier's principle. (14)

Consider the following chemical equilibrium established between dinitrogen tetroxide (N_2O_4) and nitrogen dioxide (NO_2) at a certain temperature T .



- (b) Write the equilibrium constant (K_c) expression for the reaction. (6)
- (c) The value of K_c for the reaction at T is 0.2.
One mole of pure dinitrogen tetroxide was sealed into a container of fixed 10 litre capacity. Calculate the equilibrium concentration, in moles per litre, of each of the gases at temperature T . (18)
- (d) The colour of the equilibrium mixture is paler at $0\text{ }^\circ\text{C}$ than at T , where $T > 0\text{ }^\circ\text{C}$.
Explaining your reasoning, deduce whether the decomposition of dinitrogen tetroxide into nitrogen dioxide is an exothermic or an endothermic reaction. (6)
- (e) Would there be a change in the value of K_c at T if a different initial concentration of dinitrogen tetroxide were used?
Explain your answer. (6)

8. The scheme below shows redox reactions of some organic compounds.



- (a) What is the overall colour change that occurs in the reaction vessel as phenylmethanol is converted to benzoic acid under the conditions given in the scheme?
Explain this colour change by reference to the transition metal reagent used.
Copy the structures of phenylmethanol and benzoic acid into your answerbook and mark clearly the bond(s) involving carbon in this oxidation reaction
- (i) that are broken in phenylmethanol,
(ii) that are formed in benzoic acid. (15)
- (b) Give the IUPAC names for **A** and **B** and draw their structures. (12)
- (c) Identify the reactant and a transition metal catalyst used to reduce **B** to propan-2-ol. (6)
- (d) Oxidation of **B** is very difficult while **A** can be very readily oxidised with reagents that are weaker than those shown in the scheme.
Suggest a weak oxidising reagent – a transition metal compound – that could be used to distinguish between a sample of **A** and a sample of **B**. (6)
- (e) Name an ester that is a structural isomer of propanoic acid.
Identify the alcohol and the carboxylic acid used in the synthesis of this ester. (11)
9. (a) Define (i) a base, (ii) a conjugate acid-base pair, according to Brønsted-Lowry theory.
What is the conjugate acid of H_2O ? (9)
- (b) Define pH. (3)
The pH values of 0.10 M solutions of sulfuric acid, hydrochloric acid and methanoic acid are 0.70, 1.00 and 2.37 respectively.
In terms of hydrogen ions, account for the difference in the pH values
- (i) of 0.10 M hydrochloric acid and 0.10 M sulfuric acid,
(ii) of 0.10 M hydrochloric acid and 0.10 M methanoic acid. (12)
- Use the pH value given for 0.10 M methanoic acid to calculate
- (iii) the value of the acid dissociation constant (K_a) for methanoic acid,
(iv) the pH of a 0.05 M solution of methanoic acid. (9)
- (c) Draw a clear, labelled diagram of the pH curve you would expect to obtain when 50 cm^3 of a 0.10 M NaOH solution are added gradually to 25 cm^3 of a 0.10 M methanoic acid solution.
Name a suitable indicator for a titration between these two solutions.
Explain your selection with reference to your pH curve. (17)

10. Answer any **two** of the parts (a), (b) and (c).

(2 × 25)

- (a) A student determined the relative molecular mass of a volatile liquid by vaporising a known mass of the liquid at a known temperature and pressure.

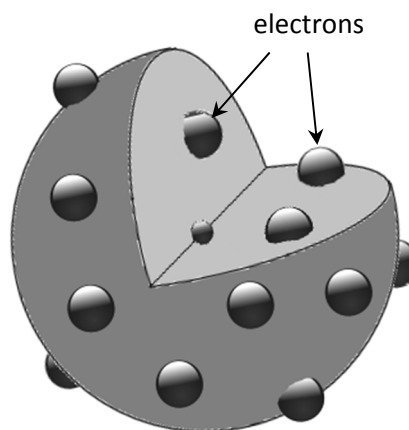
Draw a large, clearly-labelled diagram of an apparatus that could have been used in this experiment. (10)

The student recorded that 0.28 g of the volatile liquid occupied a volume of 268 cm³ when vapourised at a temperature of 98 °C and at a pressure of 101 kPa.

- (i) Calculate the number of moles of vapour present.
(ii) Find, correct to the nearest whole number, the relative molecular mass of the volatile liquid. (15)

- (b) What is an alpha particle? (6)

Before 1909 an atom was thought to consist of a sphere of positive matter with a number of small, negatively-charged electrons embedded in it, as illustrated.



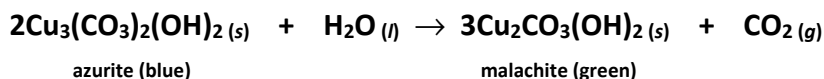
- (i) On the basis of this understanding of atomic structure, what result was expected by Rutherford when thin gold foil was first bombarded with alpha particles in 1909?
(ii) How did the actual result of this experiment differ from the expected result?
(iii) How was the model of atomic structure changed as a result? (19)

- (c) (i) What is the product of the reaction of hydrogen chloride and ethene?
Name and describe the mechanism for this reaction.
(ii) How does the geometry around the carbon atoms differ between ethene and the product molecule?
(iii) How could the same product be formed from ethane? (25)

11. Answer any **two** of the parts (a), (b) and (c).

(2 × 25)

- (a) Some of the blue pigment azurite used by an artist in a picture painted in 1600 has changed over the years into green malachite according to the following balanced equation.



Analysis shows that the only copper-containing pigments in the painting are azurite and malachite and that the picture now contains 3.81 g of copper.

- (i) What mass of pure azurite contains 3.81 g copper? (9)
- (ii) Calculate the maximum mass of malachite that will eventually be formed from this mass of azurite. (9)
- (iii) What is the volume, measured at s.t.p., of carbon dioxide that would be released from the painting in the formation of this mass of malachite? (6)
- (iv) Suggest a way that further deterioration of the painting by this chemical reaction could be prevented or delayed. (1)

- (b) Define electronegativity. (6)

Draw dot and cross diagrams to show the bonding in a molecule of

- (i) nitrogen trifluoride (**NF₃**),
- (ii) boron trifluoride (**BF₃**),
- (iii) chlorine monofluoride (**ClF**).

Use electron pair repulsion theory to predict the shape of a molecule of boron trifluoride. (12)

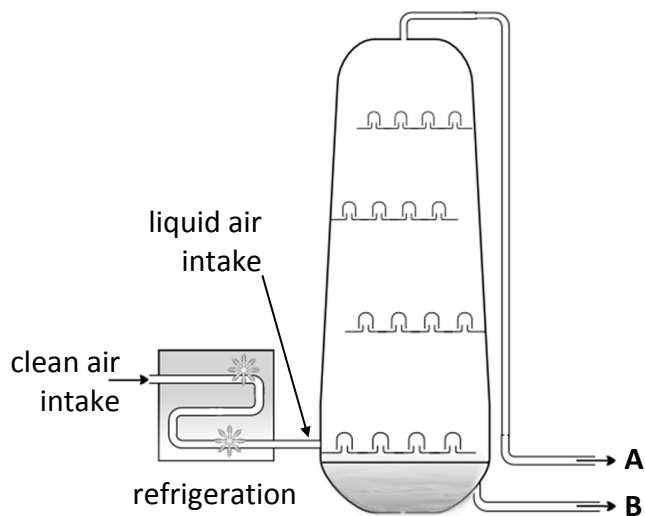
Use electronegativity values to

- (iv) indicate on your bonding diagram for chlorine monofluoride any full or partial charges that you would expect to result from the formation of the bond between chlorine and fluorine,
- (v) predict the type of bonding in chlorine monofluoride. (7)

(c) Answer part **A** or part **B**.

A

Oxygen (O_2) and nitrogen (N_2) are separated industrially by the fractional distillation of liquefied air in a column like that shown.



- (i) Give two major uses of nitrogen. (7)
- (ii) Name two components of the air feedstock that are removed prior to fractional distillation. (6)
- (iii) Explain how the air intake is liquefied prior to fractional distillation. (6)
- (iv) Which of the products, **A** or **B**, has the lower boiling point? (3)
- (v) Which of the products, **A** or **B**, is oxygen? (3)

or

B

- (i) Draw structures to show the differences that occur in the bonding in three ethene molecules when they undergo addition polymerisation and become part of a poly(ethene) chain. (10)
- (ii) Give two differences in properties, other than the difference in density, between LDPE or low-density poly(ethene) and HDPE or high-density poly(ethene). (9)
- (iii) LDPE was first synthesised industrially in 1933 but HDPE was not produced until the early 1950s.
What were the differences between the conditions used for the production of LDPE and HDPE? (6)

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