

Please write clearly in block capitals.

Centre number

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Candidate number

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Surname

Forename(s)

Candidate signature

I declare this is my own work.

A-level CHEMISTRY

Paper 3

Wednesday 17 June 2020

Morning

Time allowed: 2 hours

Materials

For this paper you must have:

- the Periodic Table/Data Booklet, provided as an insert (enclosed)
- a ruler with millimetre measurements
- a scientific calculator, which you are expected to use where appropriate.

Instructions

- Use black ink or black ball-point pen.
- Fill in the boxes at the top of this page.
- Answer **all** questions.
- You must answer the questions in the spaces provided. Do **not** write outside the box around each page or on blank pages.
- If you need extra space for your answer(s), use the lined pages at the end of this book. Write the question number against your answer(s).
- All working must be shown.
- Do all rough work in this book. Cross through any work you do not want to be marked.

Information

- The marks for questions are shown in brackets.
- The maximum mark for this paper is 90.

Advice

- You are advised to spend 70 minutes on **Section A** and 50 minutes on **Section B**.

For Examiner's Use	
Question	Mark
1	
2	
3	
4	
5	
6	
Section B	
TOTAL	



Section A

Answer all questions in this section.

0 1

This question is about emissions of oxides of nitrogen from petrol and diesel engines.

0 1 . 1

Explain how oxides of nitrogen are formed in engines.

[2 marks]

High temperatures in the engine
drive reaction between nitrogen
impurities from the fuel and
oxygen from the air

0 1 . 2

State why it is desirable to decrease emissions of oxides of nitrogen from vehicles.

[1 mark]

To prevent the formation of
acid rain

0 1 . 3

Modern diesel vehicles use diesel exhaust fluids, such as AdBlue, to decrease emissions of oxides of nitrogen.

AdBlue reacts with water in the hot exhaust gases to form ammonia.

In the presence of a catalyst the ammonia reacts with oxides of nitrogen to form nitrogen and water.

Give the oxidation state of nitrogen in each of NO_2 , NH_3 and N_2 Complete the equation for the reaction between NO_2 and NH_3

[2 marks]

Oxidation state of nitrogen in

NO_2 +4 NH_3 -3 N_2 0

Equation

3 NO_2 + 4 NH_3 → $\frac{7}{2}$ N_2 + 6 H_2O



0 1 . 4

Petrol vehicles have a catalytic converter which decreases emissions of oxides of nitrogen.

Platinum in the catalytic converter acts as a heterogeneous catalyst.

State the meaning of the term heterogeneous catalyst.

[2 marks]

a catalyst that is in a different phase to the reactants. It speeds up the reaction without being used

0 1 . 5

Some carbon particulates are also formed in both diesel and petrol vehicles.

Explain why carbon particulates are formed.

[1 mark]

incomplete combustion.

8

Turn over for the next question

Turn over ►



0 2

This question is about oxides.

0 2 . 1

Sodium oxide forms a solution with a higher pH than magnesium oxide when equal amounts, in moles, of each oxide are added separately to equal volumes of water.

State why both oxides form alkaline solutions.

Suggest why sodium oxide forms a solution with a higher pH than the solution formed from magnesium oxide.

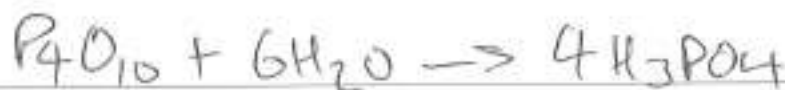
[2 marks]

The oxide ions will react with water to form hydroxide ions, raising the pH. Sodium hydroxide forms the higher pH solution as it is more soluble than magnesium hydroxide

0 2 . 2

Give an equation for the reaction between phosphorus(V) oxide and water.

[1 mark]

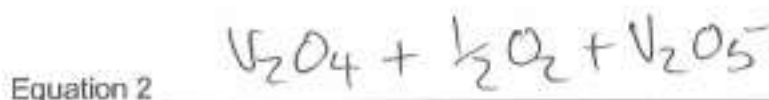


0 2 . 3

In the Contact process, sulfur(IV) oxide is converted into sulfur(VI) oxide using vanadium(V) oxide as a catalyst.

Give two equations to show how the vanadium(V) oxide acts as a catalyst in this process.

[2 marks]



Turn over for the next question

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outside the
box

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ANSWER IN THE SPACES PROVIDED

Turn over ►



0 3 . 1 Explain why complexes formed from transition metal ions are coloured.

[3 marks]

The complex ions can absorb some frequencies of visible light to promote their d orbital electrons to a higher energy. The remaining frequencies then give rise to the colour seen.

The iron content of iron tablets can be determined by colorimetry.

Method:

- Dissolve a tablet in sulfuric acid.
- Oxidise all the iron from the tablet to $\text{Fe}^{3+}(\text{aq})$.
- Convert the $\text{Fe}^{3+}(\text{aq})$ into a complex that absorbs light of wavelength 490 nm
- Make the solution up to 250 cm^3
- Measure the absorbance of light at 490 nm with a colorimeter.
- Use a calibration graph to find the concentration of the iron(III) complex.

0 3 . 2 Calculate the energy, in J, gained by each excited electron in the absorption at 490 nm

Speed of light, $c = 3.00 \times 10^8 \text{ m s}^{-1}$

Planck constant, $h = 6.63 \times 10^{-34} \text{ J s}$

[3 marks]

$$\Delta E = \frac{hc}{\lambda} = \frac{6.636 \times 10^{-34} \times 3 \times 10^8}{490 \times 10^{-9}}$$

$$= 4.06 \times 10^{-19} \text{ J}$$

Energy gained by each electron 4.06 $\times 10^{-19}$ J



- 0 3 . 3 Describe how a calibration graph is produced and used to find the concentration of the iron(III) complex.

[3 marks]

The absorbance is measured for a range of known concentrations. These absorbances are plotted against their concentrations. Then the unknown concentration's absorbance is recorded and the calibration curve of the graph used to deduce its concentration.

- 0 3 . 4 The concentration of iron(III) in the solution is $4.66 \times 10^{-3} \text{ mol dm}^{-3}$

Calculate the mass, in mg, of iron in the tablet used to make the 250 cm^3 of solution.

[2 marks]

$$n_{\text{Fe}} = 4.66 \times 10^{-3} \times \frac{250}{1000} = 0.001165 \text{ mole}$$

$$\text{mass Fe} = 4.66 \times 10^{-3} \times \frac{25}{1000} \times 55.8 = 0.065 \text{ g}$$

Mass of iron in the tablet 65 mg

11

Turn over ►



0 4

Cisplatin, $[\text{Pt}(\text{NH}_3)_2\text{Cl}_2]$, is used as an anti-cancer drug.

0 4 . 1

Cisplatin works by causing the death of rapidly dividing cells.

Name the process that is prevented by cisplatin during cell division.

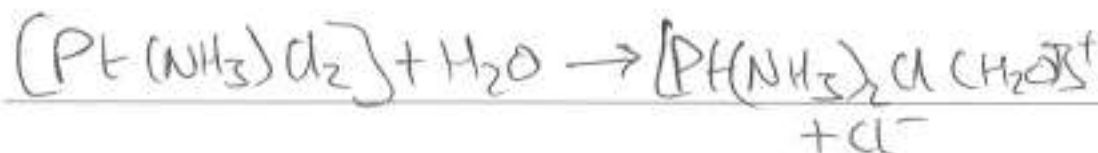
[1 mark]

DNA ReplicationAfter cisplatin enters a cell, one of the chloride ligands is replaced by a water molecule to form a complex ion, **B**.

0 4 . 2

Give the equation for this reaction.

[2 marks]



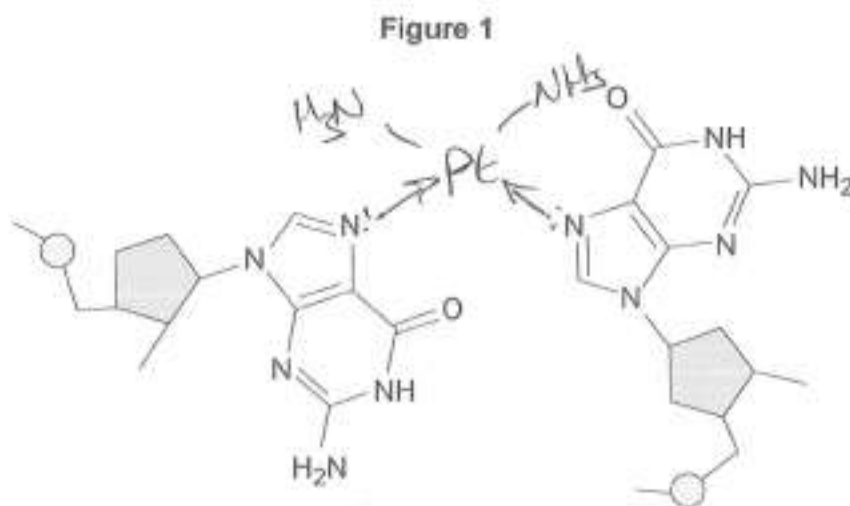
0 4 . 3

When the complex ion **B** reacts with DNA, the water molecule is replaced as a bond forms between platinum and a nitrogen atom in a guanine nucleotide. The remaining chloride ligand is also replaced as a bond forms between platinum and a nitrogen atom in another guanine nucleotide.

Figure 1 represents two adjacent guanine nucleotides in DNA.

Complete **Figure 1** to show how the platinum complex forms a cross-link between the guanine nucleotides.

[2 marks]



Question 4 continues on the next page

Turn over ►



An experiment is done to investigate the rate of reaction in Question 04.2.

- 0 4 . 4 During the experiment the concentration of cisplatin is measured at one-minute intervals.

Explain how graphical methods can be used to process the measured results, to confirm that the reaction is first order.

[3 marks]

On a graph, plot Concentration on the y-axis against time on the x-axis. Take tangents to the curve to calculate the gradients at each concentration. plot these gradients against concentration. a straight line through the origin confirms first order

In another experiment, the effect of temperature on the rate of the reaction in Question 04.2 is investigated.

Table 1 shows the results.

Table 1

Temperature T/K	$\frac{1}{T}/K^{-1}$	Rate constant k/s^{-1}	$\ln k$
293	0.00341	1.97×10^{-8}	-17.7
303	0.00330	8.61×10^{-8}	-16.3
313	0.00319	3.43×10^{-7}	-14.9
318	0.00314	6.63×10^{-7}	-14.2
323	0.00310	1.26×10^{-6}	-13.6

- 0 4 . 5 Complete Table 1.

[2 marks]



0 4 . 6 The Arrhenius equation can be written in the form

$$\ln k = \frac{-E_a}{RT} + \ln A$$

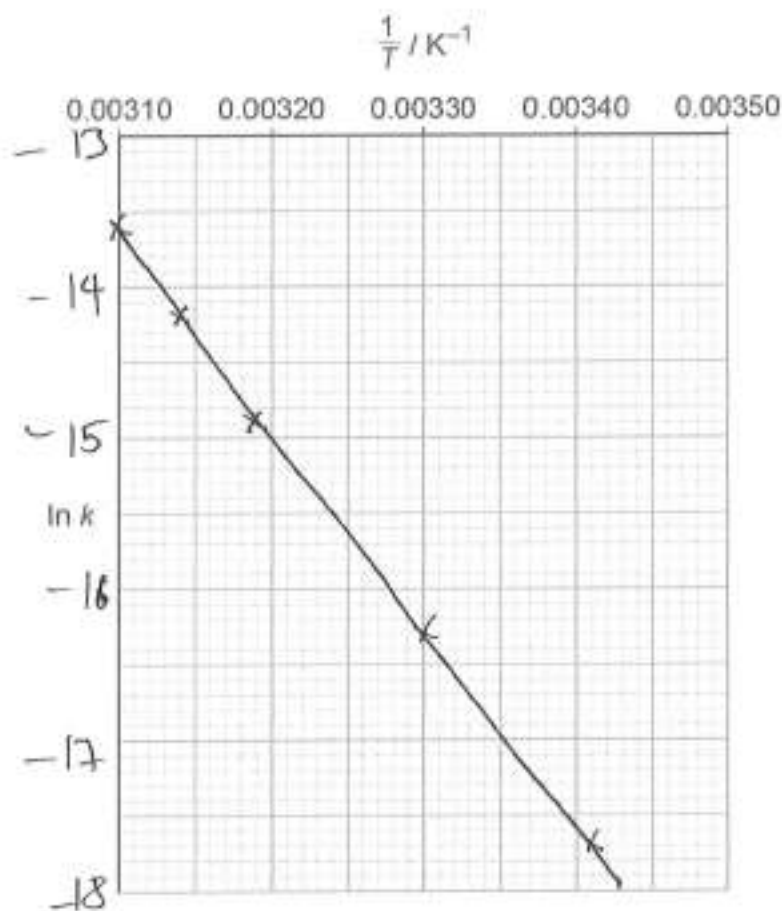
Use the data in Table 1 to plot a graph of $\ln k$ against $\frac{1}{T}$ on the grid in Figure 2.

Calculate the activation energy, E_a , in kJ mol^{-1}

The gas constant, $R = 8.31 \text{ J K}^{-1} \text{ mol}^{-1}$

[5 marks]

Figure 2



$$\text{Gradient} = -13,125 = \frac{E_a}{R}$$

$$E_a = 13,125 \times 8.31$$

$$= 109,069 \text{ J mol}^{-1}$$

$$E_a = \underline{109} \text{ kJ mol}^{-1}$$

15

Turn over ►



0 5

A bomb calorimeter can be used for accurate determination of the heat change during combustion of a fuel.

A bomb calorimeter is a container of fixed volume that withstands the change in pressure during the reaction.

The fuel is mixed with pure oxygen in the calorimeter, ignited and the temperature change is recorded.

The total heat capacity (C_{cal}) of the calorimeter is calculated using a fuel for which the heat change is known.

In an experiment to calculate C_{cal} , 2.00 g of hexane ($M_r = 86.0$) is ignited. A temperature change (ΔT) of 12.4 °C is recorded.

Under the conditions of the experiment, 1.00 mol of hexane releases 4154 kJ of energy when combusted.

0 5 . 1

The heat energy released in the calorimeter, $q = C_{\text{cal}}\Delta T$

Calculate the heat capacity (C_{cal}) in kJ K^{-1}

[3 marks]

$$n \text{ Hexane} = \frac{2}{86} = 0.0233 \text{ moles}$$

$$q = 4154 \times 0.0233 = 96.6$$

$$C_{\text{cal}} = \frac{96.6}{12.4} = 7.79 \text{ kJ K}^{-1}$$

C_{cal} 7.79 kJ K^{-1}

0 5 . 2

When the experiment is repeated with 2.00 g of octane ($M_r = 114.0$) the temperature change recorded is 12.2 °C

Calculate the heat change, in kJ mol^{-1} , for octane in this combustion reaction.

If you were unable to calculate a value for C_{cal} in Question 05.1, use 6.52 kJ K^{-1} (this is not the correct value).

[2 marks]

$$q = C_{\text{cal}} \Delta T = 7.79 \times 12.2 = 95 \text{ kJ}$$

$$n \text{ Octane} = \frac{2}{114} = 0.0175 \text{ moles}$$

$$\text{heat change} = \frac{95}{0.0175} = 5417 \text{ kJ mol}^{-1}$$

Heat change 5417 kJ mol^{-1}



- 0 5 . 3 State why the heat change calculated from the bomb calorimeter experiment is **not** an enthalpy change. [1 mark]

The pressure in a bomb calorimeter
is not constant

- 0 5 . 4 The thermometer used to measure the temperature change of 12.2 °C in Question 05.2 has an uncertainty of ± 0.1 °C in each reading.

Calculate the percentage uncertainty in this use of the thermometer.

Suggest **one** change to this experiment that decreases the percentage uncertainty while using the same thermometer. [2 marks]

$$\frac{0.2}{12.2} \times 100 = 1.64\%$$

Percentage uncertainty 1.64

Change use a larger mass of fuel
to increase ΔT

Turn over for the next question

Turn over ►



0 6

Standard electrode potentials are measured by comparison with the standard hydrogen electrode.

0 6 . 1

State the substances and conditions needed in a standard hydrogen electrode.

[3 marks]

H_2 gas at 100 kPa

1 mol dm⁻³ HCl

Platinum electrode

298 K

It is difficult to ensure consistency with the setup of a standard hydrogen electrode. A $Cu^{2+}(aq)/Cu(s)$ electrode ($E^\ominus = +0.34$ V) can be used as a secondary standard.

A student does an experiment to measure the standard electrode potential for the $TiO^{2+}(aq)/Ti(s)$ electrode using the $Cu^{2+}(aq)/Cu(s)$ electrode as a secondary standard.

A suitable solution containing the acidified $TiO^{2+}(aq)$ ion is formed when titanium(IV) oxysulfate ($TiOSO_4$) is dissolved in 0.50 mol dm⁻³ sulfuric acid to make 50 cm³ of solution.

0 6 . 2

Describe an experiment the student does to show that the standard electrode potential for the $TiO^{2+}(aq)/Ti(s)$ electrode is -0.88 V

The student is provided with:

- the $Cu^{2+}(aq)/Cu(s)$ electrode set up ready to use
- solid titanium(IV) oxysulfate ($M_r = 159.9$)
- 0.50 mol dm⁻³ sulfuric acid
- a strip of titanium
- laboratory apparatus and chemicals.

Your answer should include details of:

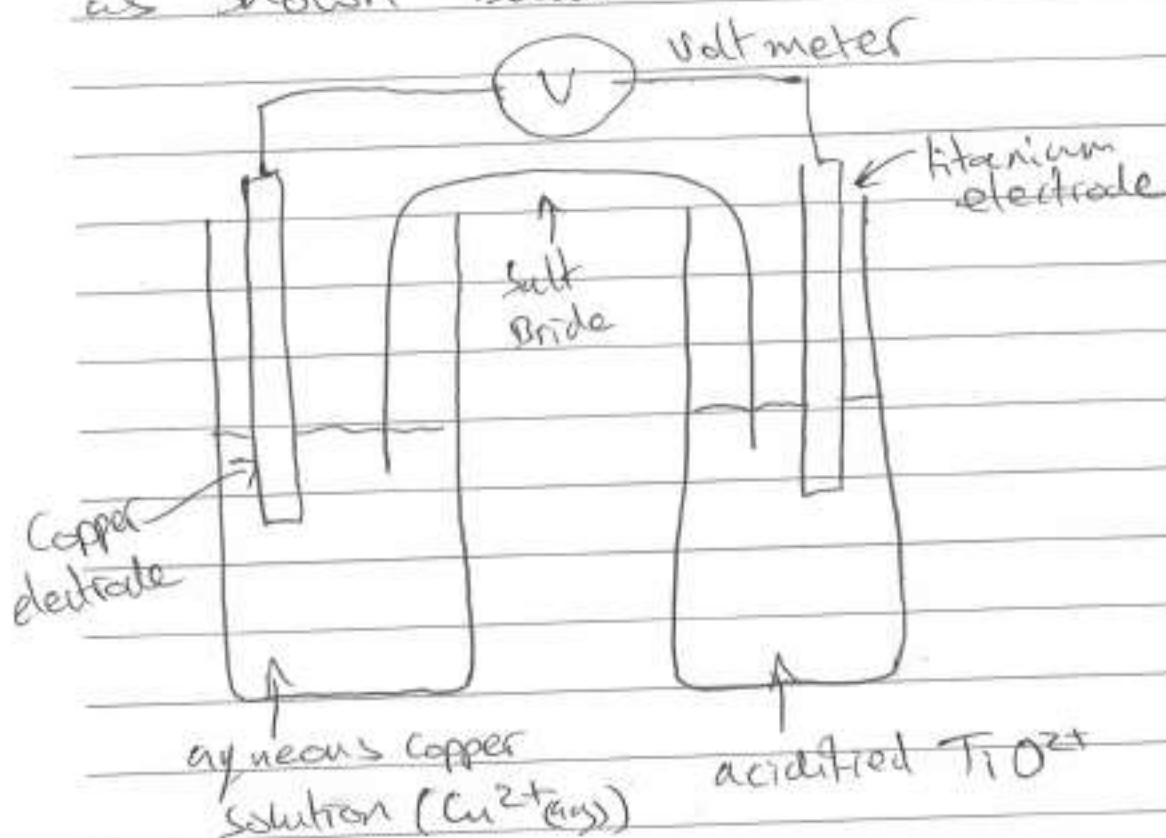
- how to prepare the solution of acidified $TiO^{2+}(aq)$
- how to connect the electrodes
- measurements taken
- how the measurements should be used to calculate the standard electrode potential for the $TiO^{2+}(aq)/Ti(s)$ electrode.

[6 marks]

Firstly a solution of acidified $TiOSO_4$ should be prepared. Weigh 800g of $TiOSO_4$ and dissolve in 0.5 mol dm⁻³ H_2SO_4 . Transfer to a



Volumetric flask and make up to the mark (either 25cm^3 or 250cm^3 as needed) with deionised water. Then a cell should be set up as shown below.



The salt bridge is made by soaking filter paper in an aqueous salt such as NaOH to complete the cell.

To determine the E^{\ominus} half cell of $\text{Ti}/\text{TiO}^{2+}$ the reading on the voltmeter should be recorded. To calculate the value we then subtract the E^{\ominus} half cell of

Turn over ►



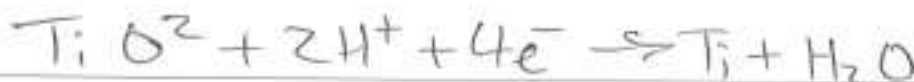
Copper from the total cell EMF
(The volt meter reading)



0 6 . 3

Give the half-equation for the electrode reaction in the $\text{TiO}^{2+}(\text{aq})/\text{Ti}(\text{s})$ electrode in acidic conditions.

[1 mark]



0 6 . 4

Table 2 shows some electrode potential data.

Table 2

Electrode reaction	E^{\ominus} / V
$2\text{H}^{+}(\text{aq}) + 2\text{e}^{-} \rightarrow \text{H}_2(\text{g})$	0.00
$\text{Cu}^{2+}(\text{aq}) + 2\text{e}^{-} \rightarrow \text{Cu}(\text{s})$	+0.34
$\text{NO}_3^{-}(\text{aq}) + 4\text{H}^{+}(\text{aq}) + 3\text{e}^{-} \rightarrow \text{NO}(\text{g}) + 2\text{H}_2\text{O}(\text{l})$	+0.96

Use the data in Table 2 to explain why copper does **not** react with most acids but does react with nitric acid.

Give an equation for the reaction between copper and nitric acid.

[3 marks]

Explanation The E^{\ominus} value for the copper half cell is negative with most acids (-0.34). Nitric acid's half cell value is however more positive than copper's and so they can react

Equation



13

Turn over for Section B

Turn over ►




Section B

Answer **all** questions in this section.Only **one** answer per question is allowed.

For each question completely fill in the circle alongside the appropriate answer.

CORRECT
METHOD

WRONG METHODS

If you want to change your answer you must cross out your original answer as shown. If you wish to return to an answer previously crossed out, ring the answer you now wish to select as shown. You may do your working in the blank space around each question but this will not be marked.
Do **not** use additional sheets for this working.

0 7

When heated, a sample of potassium chlorate(V) (KClO_3) produced 67.2 cm^3 of oxygen, measured at 298 K and 110 kPa 

What is the amount, in moles, of potassium chlorate(V) that has decomposed?

The gas constant, $R = 8.31 \text{ J K}^{-1} \text{ mol}^{-1}$

[1 mark]

A 9.95×10^{-4} B 1.99×10^{-3} C 2.99×10^{-3} D 4.48×10^{-3} 

0 8

Which has a bond angle of 109.5° ?

[1 mark]

A C (diamond)

B C (graphite)

C NH_2^- D NH_3

0 9

Which reaction has an enthalpy change equal to the standard enthalpy of formation of silver iodide?

[1 mark]

A $\text{Ag}(\text{g}) + \frac{1}{2} \text{I}_2(\text{g}) \rightarrow \text{AgI}(\text{s})$ B $\text{Ag}(\text{s}) + \frac{1}{2} \text{I}_2(\text{s}) \rightarrow \text{AgI}(\text{s})$ C $\text{Ag}^+(\text{g}) + \text{I}^-(\text{g}) \rightarrow \text{AgI}(\text{s})$ D $\text{Ag}^+(\text{aq}) + \text{I}^-(\text{aq}) \rightarrow \text{AgI}(\text{s})$

1 0

Some bond enthalpies are given.

Bond	C-H	O-H	O=O	C=O
Bond enthalpy/ kJ mol^{-1}	412	463	496	743

Which is the enthalpy change of this reaction in kJ mol^{-1} ?

[1 mark]

A +698

B +228

C -228

D -698

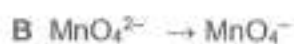
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1 1

In which conversion is the metal reduced?

[1 mark]



1 2

The rate expression for the reaction between X and Y is

$$\text{rate} = k [\text{X}]^2 [\text{Y}]$$

Which statement is correct?

[1 mark]

A The rate constant has units $\text{mol}^{-1} \text{dm}^3 \text{s}^{-1}$

B The rate of the reaction is halved if the concentration of X is halved and the concentration of Y is doubled.

C The rate increases by a factor of 16 if the concentration of X is tripled and the concentration of Y is doubled.

D The rate constant is independent of temperature.

1 3

Which statement about pH is correct?

[1 mark]

A The pH of a weak base is independent of temperature.

B At temperatures above 298 K, the pH of pure water is less than 7.

C The pH of 2.0 mol dm^{-3} nitric acid is approximately 0.30D The pH of 0.10 mol dm^{-3} sulfuric acid is greater than that of 0.10 mol dm^{-3} hydrochloric acid.

1 4

A 0.10 mol dm^{-3} aqueous solution of an acid is added slowly to 25 cm^3 of a 0.10 mol dm^{-3} aqueous solution of a base.

Which acid–base pair has the highest pH at the equivalence point?

[1 mark]

A CH_3COOH and NaOH

B CH_3COOH and NH_3

C HCl and NaOH

D HCl and NH_3

1 5

In the test for a halide ion in aqueous solution, dilute nitric acid is added before the addition of silver nitrate solution.

Why is nitric acid added?

[1 mark]

A It increases the concentration of nitrate ions.

B It prevents the precipitation of silver compounds other than halides.

C It prevents the silver nitrate being precipitated.

D It provides the acidic solution required for precipitation.

1 6

Which shows the major product(s) formed when chlorine reacts with cold, dilute, aqueous sodium hydroxide?

[1 mark]

A NaCl only

B NaClO only

C NaCl and NaClO

D NaCl and NaClO_3

Turn over ►



1 7

Which shows the electron configuration of an atom of a transition metal?

[1 mark]

A [Ar] 4s²3d⁰B [Ar] 4s²3d⁵C [Ar] 4s²3d¹⁰D [Ar] 4s²3d¹⁰4p¹

1 8

Which will **not** act as a ligand in the formation of a complex ion?

[1 mark]

A CH₄

B CO

C H₂OD NH₃

1 9

Which shows the correct oxidation state and co-ordination number of cobalt in [Co(NH₃)₅Cl]Cl₂?

[1 mark]

	oxidation state	co-ordination number	
A	+2	5	<input type="radio"/>
B	+2	6	<input type="radio"/>
C	+3	5	<input type="radio"/>
D	+3	6	<input checked="" type="radio"/>



2 0

Which statement is **not** correct?

[1 mark]

- A CuCl_4^{2-} is square planar.
- B NH_4^+ is tetrahedral.
- C $[\text{Co}(\text{H}_2\text{NCH}_2\text{CH}_2\text{NH}_2)_3]^{2+}$ is octahedral.
- D $[\text{Fe}(\text{H}_2\text{O})_6]^{2+}$ is octahedral.

2 1

Which compound decolourises acidified potassium manganate(VII) solution?

[1 mark]

- A $\text{Al}_2(\text{SO}_4)_3$
- B CuSO_4
- C FeSO_4
- D $\text{Fe}_2(\text{SO}_4)_3$

2 2

Which has *E-Z* isomers?

[1 mark]

- A $\text{C}_2\text{H}_2\text{Br}_2$
- B $\text{C}_2\text{H}_3\text{Br}$
- C $\text{C}_2\text{H}_4\text{Br}_2$
- D $\text{C}_2\text{H}_5\text{Br}$

Turn over for the next question

Turn over ►



2 3

Which is the mechanism for this conversion?



[1 mark]

A Addition-elimination B Electrophilic substitution C Free-radical substitution D Nucleophilic substitution

2 4

Which compound decolourises bromine water in the absence of sunlight?

[1 mark]

A $\text{CH}_3\text{CH}_2\text{CH}_2\text{Br}$ D $\text{CH}_3\text{CH}_2\text{CHCH}_2$

2 5

Which compound reacts to form a ketone when warmed with an acidified solution of potassium dichromate(VI)?

[1 mark]

A $\text{CH}_3\text{CH}_2\text{CH}_2\text{OH}$ B $(\text{CH}_3)_2\text{CHOH}$ C $\text{CH}_3\text{CH}_2\text{CHO}$ D $(\text{CH}_3)_2\text{CHCOOH}$ 

2 | 6

Which does **not** contain an asymmetric carbon atom?

[1 mark]



2 | 7

Which reaction involves addition-elimination?

[1 mark]



2 | 8

Which compound reacts with hydrogen bromide to give 2-bromo-3-methylbutane as the major product?

[1 mark]



Turn over for the next question

Turn over ►



2 9

Which forms a polymer with $\text{ClOC}(\text{CH}_2)_6\text{COCl}$?

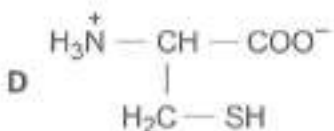
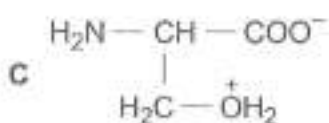
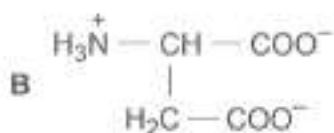
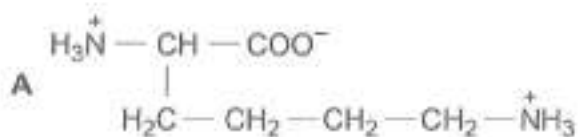
[1 mark]



3 0

Which structure shows the zwitterion of an amino acid?

[1 mark]



3 1

What is the minimum volume, in cm^3 , of 0.02 mol dm^{-3} KMnO_4 solution needed to oxidise 0.01 mol of VO^{2+} ?

[1 mark]

A 10

B 50

C 100

D 200



3 2

Which is the concentration of NaOH(aq), in mol dm⁻³, that has pH = 14.30? $K_w = 1.00 \times 10^{-14} \text{ mol}^2 \text{ dm}^{-6}$ at 25 °C

[1 mark]

A -1.16

B 5.01×10^{-15} C 2.00×10^{14}

D 2.00

3 3

What are the units of the rate constant for a third order reaction?

[1 mark]

A mol dm⁻³ s⁻¹B mol⁻¹ dm³ s⁻¹C mol² dm⁻⁶ s⁻¹D mol⁻² dm⁶ s⁻¹

3 4

What is the pH of 0.015 mol dm⁻³ sulfuric acid?

[1 mark]

A -1.82

B -1.52

C 1.52

D 1.82

Turn over for the next question

Turn over ►



3 5

Which compound is formed when phenyl benzenecarboxylate is hydrolysed under acidic conditions?

[1 mark]

A $C_6H_5CH_2OH$ B C_6H_5CHO C $C_6H_5COCH_3$ D C_6H_5COOH

3 6

A student rinsed the apparatus before starting an acid-base titration. The results of the titration showed that the volume of acid added from the burette was larger than expected.

Which is a possible reason for this?

[1 mark]

A The conical flask was rinsed with water before the titration.

B The walls of the conical flask were rinsed with water during the titration.

C The pipette was rinsed only with water.

D The burette was rinsed only with water.

30

END OF QUESTIONS

