

# A Level Chemistry A

**H432/01** Periodic table, elements and physical chemistry

# **Tuesday 13 June 2017 – Afternoon**

Time allowed: 2 hours 15 minutes

#### You must have:

 the Data Sheet for Chemistry A (sent with general stationery)

#### You may use:

· a scientific or graphical calculator



First name	
Last name	
Centre number	Candidate number

### **INSTRUCTIONS**

- Use black ink. You may use an HB pencil for graphs and diagrams.
- Complete the boxes above with your name, centre number and candidate number.
- Answer all the questions.
- Write your answer to each question in the space provided. If additional space is required, use the lined page(s) at the end of this booklet. The question number(s) must be clearly shown.
- · Do **not** write in the barcodes.

### **INFORMATION**

- The total mark for this paper is 100.
- The marks for each question are shown in brackets [ ].
- Quality of extended responses will be assessed in questions marked with an asterisk (\*).
- · This document consists of 28 pages.



## **SECTION A**

# You should spend a maximum of 20 minutes on this section.

# Write your answer to each question in the box provided.

Answer all the questions.

1 Which atom is **not** an isotope of iodine?

	Number of neutrons	Mass number
Α	72	125
В	74	127
С	75	128
D	77	129

			77	129
	You	ır answer		
2	Wha	at is the bo	onding between the	e ligands and the met
	Α	Metallic		
	В	Ionic		
	С	Hydrogen	1	
	D	Dative co	valent	
	You	ır answer		
3	Wha	at is the ox	xidation number of	Mn in K <sub>2</sub> MnO <sub>4</sub> ?
	Α	+4		
	В	+5		
	С	+6		
	D	+7		
	You	r answer		

4	Whi	ch calcium compound contains the <b>greatest</b> percentage by mass of calcium?	
	Α	calcium carbonate	
	В	calcium nitrate	
	С	calcium hydroxide	
	D	calcium sulfate	
	You	r answer	[1]
5	0.02	200 mol of calcium oxide is reacted completely with 2.00 mol dm $^{-3}$ HC $\it l$ .	
	Wha	at is the volume, in cm $^3$ , of 2.00 mol dm $^{-3}$ HC $l$ required for this reaction?	
	Α	15	
	В	20	
	С	30	
	D	60	
	You	r answer	[1]
6	Hov	v many electrons are removed from $2.02 \times 10^{-2}$ g of Ne(g) atoms to form Ne <sup>+</sup> (g) ions?	
	Α	$3.36 \times 10^{-26}$	
	В	$1.66 \times 10^{-27}$	
	С	$6.02 \times 10^{20}$	
	D	$1.22 \times 10^{22}$	
	You	r answer	[1]

7	Silicon	can be	made b	y heating	silicon	tetrachloride,	$SiCl_A$ ,	with	zinc
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$$\mathrm{SiC}l_4$$
 + 2Zn  $\rightarrow$  Si + 2ZnC $l_2$ 

 $8.50\,\mathrm{g}$  of  $\mathrm{SiC}\,l_4$  is reacted with an excess of zinc. The percentage yield of silicon is 90%.

What is the mass of silicon made?

- **A** 1.26 g
- **B** 1.31g
- **C** 1.40 g
- **D** 1.55 g

[1]

**8** Four pairs of solutions are mixed.

Which pair of solutions forms a white precipitate?

- **A** NH<sub>4</sub>Cl(aq) and NaOH(aq)
- **B** KBr(aq) and AgNO<sub>3</sub>(aq)
- ${f C}$  FeC $l_3$ (aq) and NH $_3$ (aq)
- $\mathbf{D} \quad \operatorname{Cr}_2(\operatorname{SO}_4)_3(\operatorname{aq}) \text{ and } \operatorname{BaC} l_2(\operatorname{aq})$

Your answer			[1]
Your answer			[1

Enthalpy values are provided below. 9

$$H_2(g) + I_2(g) \rightarrow 2HI(g)$$
  $\Delta_r H = -9 \text{ kJ mol}^{-1}$ 

$$\Delta_r H = -9 \text{ kJ mol}^{-1}$$

Bond	Bond enthalpy /kJmol <sup>-1</sup>
H–H	+436
I-I	+151

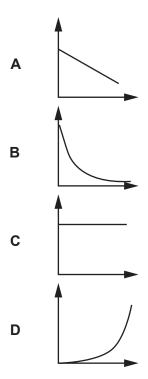
What is the bond enthalpy, in kJ mol<sup>-1</sup>, of the H–I bond?

- Α -596
- В -298
- C +298
- D +596

[1]

**10** A reaction is zero order with respect to a reactant **A**.

Which concentration-time graph for reactant **A** is the correct shape?



[1]

Your answer

11	Aqu	neous Cr <sup>3+</sup> ions are reacted with an excess of aqueous sodium hydroxide.	
	Whi	ich product is formed?	
	Α	Cr(OH) <sub>6</sub> <sup>3–</sup>	
	В	Cr(OH) <sub>3</sub>	
	С	$[Cr(OH)_4(H_2O)_2]^-$	
	D	$[Cr(OH)_4]^{3-}$	
	You	r answer	[1]
12	<b>HA</b> 25.0	and <b>HB</b> are two strong monobasic acids.  0 cm <sup>3</sup> of 6.0 mol dm <sup>-3</sup> <b>HA</b> is mixed with 45.0 cm <sup>3</sup> of 3.0 mol dm <sup>-3</sup> <b>HB</b> .	
	Wha	at is the H <sup>+</sup> (aq) concentration, in mol dm <sup>-3</sup> , in the resulting solution?	
	Α	1.9	
	В	2.1	
	С	4.1	
	D	4.5	
	You	r answer	[1]
13	A m	ixture of $\rm N_2$ and $\rm O_2$ gases has a total pressure of 1.42 atm. mole fraction of $\rm N_2$ is 0.700.	
	Wha	at is the partial pressure, in atm, of O <sub>2</sub> in the mixture?	
	Α	0.211	
	В	0.426	
	С	0.493	
	D	0.994	
	You	r answer	[1]

14 A cell is constructed from the two redox systems below.

$$Cu^{2+}(aq) + 2e^{-} \rightleftharpoons Cu(s)$$
  $E^{\theta} = +0.34 \text{ V}$   
 $Ag^{+}(aq) + e^{-} \rightleftharpoons Ag(s)$   $E^{\theta} = +0.80 \text{ V}$ 

Which statement(s) is/are correct for the cell?

- 1 The cell potential is 1.14 V.
- 2 The reaction at the copper electrode is  $Cu(s) \rightarrow Cu^{2+}(aq) + 2e^{-}$ .
- 3 The silver electrode increases in mass.
- **A** 1, 2 and 3
- B Only 1 and 2
- C Only 2 and 3
- **D** Only 1



- 15 Which electron configuration(s) is/are correct?
  - 1 Cr atom: 1s<sup>2</sup>2s<sup>2</sup>2p<sup>6</sup>3s<sup>2</sup>3p<sup>6</sup>3d<sup>5</sup>4s<sup>1</sup>
  - 2 Cu atom:  $1s^22s^22p^63s^23p^63d^{10}4s^1$
  - $3 \quad \text{Fe}^{2+} \text{ ion: } 1s^22s^22p^63s^23p^63d^54s^1 \\$
  - **A** 1, 2 and 3
  - B Only 1 and 2
  - C Only 2 and 3
  - D Only 1



## **SECTION B**

Answer all the questions.

- 16 This question is about ions and compounds containing hydrogen.
  - (a) Lithium aluminium hydride,  $LiAlH_4$ , contains the  $AlH_4^-$  ion.

Draw a 'dot-and-cross' diagram to show the bonding in an  $\mathrm{A}l\mathrm{H_4}^-$  ion.

Show outer electrons only.

[1]

(b) Nitrogen forms  $NH_4^+$  and  $NH_2^-$  ions.

Predict the name of the shape of, and H–N–H bond angle in,  $\mathrm{NH_4}^+$  and  $\mathrm{NH_2}^-.$ 

lon	Name of shape	H–N–H bond angle
NH <sub>4</sub> <sup>+</sup>		
NH <sub>2</sub> <sup>-</sup>		

[2]

(c) Nitrogen, phosphorus and arsenic are in Group 15 (5) of the periodic table.

The boiling points of their hydrides are shown below.

Element	Hydride	Boiling point/°C
N	NH <sub>3</sub>	-33
Р	PH <sub>3</sub>	-88
As	AsH <sub>3</sub>	<b>–</b> 55

(i)	Explain why the boiling point of $\mathrm{PH}_3$ is lower than the boiling point of $\mathrm{NH}_3$ .
	[2
(ii)	Explain why the boiling point of $\mathrm{PH}_3$ is lower than the boiling point of $\mathrm{AsH}_3$ .
	[2

17	This	s que	estion is about Group 2 and Group 17 (7).
	(a)	Bar	ium chloride can be prepared from barium hydroxide in a neutralisation reaction.
		Wri	te the equation for this reaction. State symbols are <b>not</b> required.
	(b)	The	reactivity of the Group 2 elements Mg–Ba increases down the group.
		Exp	lain why.
			[3]
	(c)	On	gently heating, the compound $KClO_3$ reacts as shown in the equation.
		Thi	$4KClO_3(s) \rightarrow KCl(s) + 3KClO_4(s)$
			s reaction is an example of disproportionation.
		(i)	State what is meant by disproportionation and use oxidation numbers to show that disproportionation has taken place.
		(ii)	What is the systematic name for $\mathrm{KC}l\mathrm{O}_4$ ?
			[1]

(d) Two changes are described below.

For each change,

- write an equation, including state symbols, state and explain how the entropy changes.

(i)	The reaction of aqueous barium nitrate with aqueous sodium sulfate.	
	Full equation with state symbols	
	Explanation of entropy change	
		[2]
(ii)	The change that accompanies the standard enthalpy change of atomisation of iodine	).
	Equation with state symbols	
	Explanation of entropy change	
		. [2]

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- **18** This question is about free energy changes,  $\Delta G$ , enthalpy changes,  $\Delta H$ , and temperature, T.
  - (a) The Gibbs' equation is shown below.

$$\Delta G = \Delta H - T \Delta S$$

A chemist investigates a reaction to determine how  $\Delta G$  varies with T. The results are shown in **Fig. 18.1**.

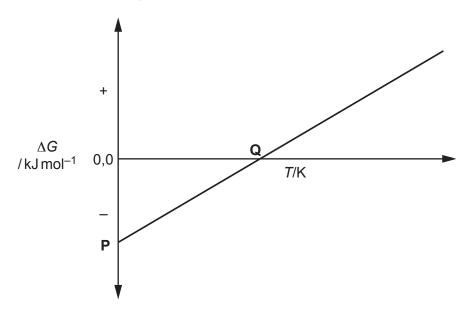


Fig. 18.1

What is significant about the gradient of the line and the values <b>P</b> and <b>Q</b> shown in <b>Fig. 18.1</b> ? Explain your reasoning.
[4]

(b)	Iron can be extracted from its ore Fe <sub>3</sub> O <sub>4</sub> using carbon.
	Several equilibria are involved including <b>equilibrium 18.1</b> , shown below.

			[1]
(i)	Why is <b>equilib</b>	rium 18.1 a heterogeneous equilibrium?	
equilibrium 18.1		$Fe_3O_4(s) + 4C(s) \iff 3Fe(s) + 4CO(g)$	$\Delta H = +676.4 \text{ kJ mol}^{-1}$ $\Delta S = +703.1 \text{ J K}^{-1} \text{ mol}^{-1}$

[1]

- (iii) The forward reaction in equilibrium 18.1 is only feasible at high temperatures.
  - Show that the forward reaction is **not** feasible at 25 °C.
  - Calculate the minimum temperature, in K, for the forward reaction to be feasible.

minimum temperature = ..... K [3]

(iv) Another equilibrium involved in the extraction of iron from  ${\rm Fe_3O_4}$  is shown below.

$$Fe_3O_4(s) + 4CO(g) \implies 3Fe(s) + 4CO_2(g)$$
  $\Delta H = -13.5 \text{ kJ mol}^{-1}$ 

Enthalpy changes of formation,  $\Delta_{\rm f}H$ , for  ${\rm Fe_3O_4(s)}$  and  ${\rm CO_2(g)}$  are shown in the table.

Compound	$\Delta_{\rm f}H/{\rm kJmol^{-1}}$
Fe <sub>3</sub> O <sub>4</sub> (s)	-1118.5
CO <sub>2</sub> (g)	-393.5

Calculate the enthalpy change of formation,  $\Delta_{\!f} H,$  for CO(g).

 $\Delta_{\rm f}H$ , for CO(g) = .....kJ mol<sup>-1</sup> [3]

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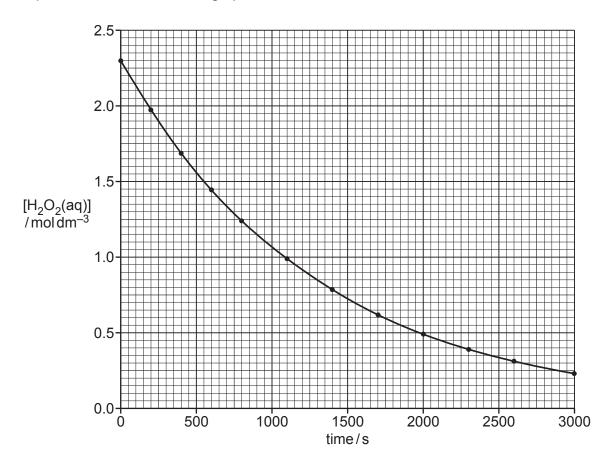
**19** Aqueous solutions of hydrogen peroxide,  $H_2O_2(aq)$ , decompose as in the equation below.

$$2H_2O_2(aq) \rightarrow 2H_2O(I) + O_2(g)$$

A student investigates the decomposition of  $\rm H_2O_2(aq)$  by measuring the volume of oxygen gas produced over time. All gas volumes are measured at room temperature and pressure.

The student uses  $25.0\,\mathrm{cm^3}$  of  $2.30\,\mathrm{mol\,dm^{-3}}$   $\mathrm{H_2O_2}$ .

From the results, the student determines the concentration of  $H_2O_2(aq)$  at each time. The student then plots a concentration—time graph.



(a) Determine the total volume of oxygen, measured at room temperature and pressure, that the student should be prepared to collect in this investigation.

Suggest apparatus that would allow this gas volume to be collected, indicating clearly the scale of working.

(b)	Suggest a different experimental method that would allow the rate of this reaction to be followed over time.
	[1]
(c)*	Determine the initial rate of reaction, the order with respect to H <sub>2</sub> O <sub>2</sub> , and the rate constant.
	Your answer must show full working on the graph and on the lines below.
	[6]

20	This	<b>question</b>	is	about	equilibrium	reactions.

(a)	Hydrogen gas is manufactured by the chemical industry using the reaction of methane and
	steam. This is a reversible reaction, shown in <b>equilibrium 20.1</b> below.

equilibrium 20.1	$CH_4(g) + H_2O(g) \rightleftharpoons$	$3H_2(g) + CO(g)$	$\Delta H = +210 \mathrm{kJ} \mathrm{mol}^{-1}$
for a maximum yield conditions used by the		ibrium 20.1, and expl be different.	essure and temperature ain why the operational
			[4]

**(b)** A chemist investigates the equilibrium reaction between sulfur dioxide, oxygen, and sulfur trioxide, shown below.

$$2SO_2(g) + O_2(g) \rightleftharpoons 2SO_3(g)$$

- The chemist mixes together SO<sub>2</sub> and O<sub>2</sub> with a catalyst.
- The chemist compresses the gas mixture to a volume of 400 cm<sup>3</sup>.
- The mixture is heated to a constant temperature and is allowed to reach equilibrium without changing the total gas volume.

The equilibrium mixture contains  $0.0540 \, \mathrm{mol} \, \mathrm{SO}_2$  and  $0.0270 \, \mathrm{mol} \, \mathrm{O}_2$ .

At the temperature used, the numerical value for  $K_c$  is  $3.045 \times 10^4 \, \text{dm}^3 \, \text{mol}^{-1}$ .

(i) Write the expression for  $K_{\rm c}$  and the units of  $K_{\rm c}$  for this equilibrium.

[2]

(ii) Determine the amount, in mol, of SO<sub>3</sub> in the equilibrium mixture at this temperature.

Give your final answer to an appropriate number of significant figures.

Show all your working.

equilibrium amount of SO<sub>3</sub> = ..... mol **[4]** 

21	This Etha 25°	question is about the properties and reactions of ethanoic acid, CH $_3$ COOH. anoic acid is a weak acid with an acid dissociation constant, $K_{\rm a}$ , of 1.75 $ imes$ 10 $^{-5}$ mol dm $^{-3}$ at C.
	(a)	A student uses a pH meter to measure the pH of a solution of $\mathrm{CH_{3}COOH}$ at 25 °C. The measured pH is 2.440.
		Calculate the concentration of ethanoic acid in the solution.
		Give your answer to <b>three</b> significant figures.
		concentration = mol dm <sup>-3</sup> [3]
	(b)	Ethanoic acid is added to another weak acid, fluoroethanoic acid, FCH <sub>2</sub> COOH $(K_a = 2.19 \times 10^{-3}  \text{mol dm}^{-3})$ . An equilibrium is set up containing two acid-base pairs.
		Complete the equilibrium and label the conjugate acid-base pairs as A1, B1 and A2, B2.
		$\mathrm{CH_{3}COOH} + \mathrm{FCH_{2}COOH} \Longrightarrow \dots + \dots + \dots$
		[2]

(c)	The student plans to prepare a buffer solution that has a pH of 4.50. The buffer solution will
	contain ethanoic acid, CH <sub>3</sub> COOH, and sodium ethanoate, CH <sub>3</sub> COONa.

The student plans to add 9.08 g  $\rm CH_3COONa$  to 250 cm $^3$  of 0.800 mol dm $^{-3}$   $\rm CH_3COOH$ . The student assumes that the volume of the solution does not change.

(i)	Show by calculation whether,	or not,	the student's	experimental	method	would	produce
	the required pH.						

Show	all	your	working	J
------	-----	------	---------	---

	Explain your reasoning.
	Suggest whether the pH of the buffer solution would be the same, greater than, or less than your calculated value in <b>(c)(i)</b> .
(ii)	When the student prepares the buffer solution, the volume of solution increases slightly.

[5]

22 This question is about redox, electrode potentials and feasibility.

**Table 22.1** shows standard electrode potentials for four redox systems. You need to use this information to answer the questions below.

Redox system	Equation	E <sup>⊕</sup> /V
1	$Zn^{2+}(aq) + 2e^{-} \rightleftharpoons Zn(s)$	-0.76
2	$SO_4^{2-}(aq) + 2H^+(aq) + 2e^- \implies SO_3^{2-}(aq) + H_2O(I)$	+0.17
3	$Fe^{3+}(aq) + e^{-} \rightleftharpoons Fe^{2+}(aq)$	+0.77
4	$MnO_4^-(aq) + 8H^+(aq) + 5e^- \implies Mn^{2+}(aq) + 4H_2O(I)$	+1.51

## **Table 22.1**

- (a) A standard cell is set up in the laboratory based on redox systems 1 and 3 and the standard cell potential is measured.
  - (i) Draw a labelled diagram to show how this cell could be set up to measure its standard cell potential.

Include details of the apparatus, solutions and the standard conditions required to measure this standard cell potential.

Standard conditions	
	[4]
Predict the standard cell potential of this cell.	

standard cell potential = ...... V [1]

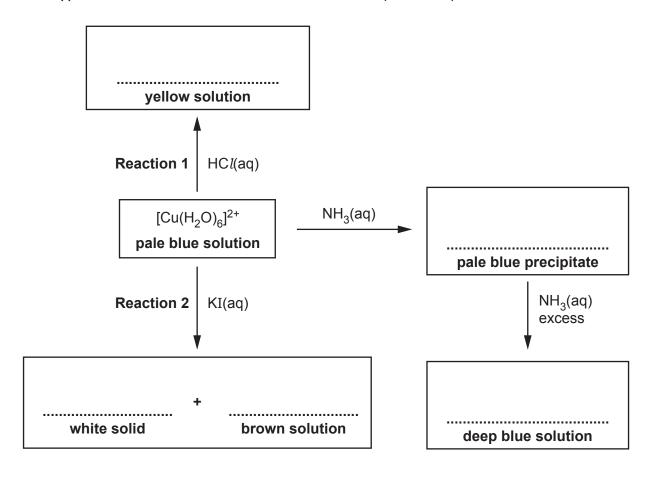
(ii)

(b)	In <b>Table 22.1</b> , what is the strongest reducing agent and the strongest oxidising agent?
	Strongest reducing agent
	Strongest oxidising agent
(c)	Electrode potentials can be used to predict the feasibility of reactions.
	Construct an overall equation for the predicted reaction between the species in redox systems 2 and 4.
	[2]

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- 23 This question is about reactions of ions and compounds of transition elements.
  - (a) The flowchart shows reactions of the complex ion  $[Cu(H_2O)_6]^{2+}$ .
    - (i) In the boxes, write down the formulae of the species responsible for the observations.



(ii) Name the type of reaction for Reaction 1 and Reaction 2.

Reaction 1

Reaction 2

[2]

[5]

(b)*	$^{t}$ A hydrated nickel(II) complex, $\mathbf{A}$ , is heated in a crucible to remove the water of crystallisation.
	The anhydrous complex <b>B</b> is formed. The results are shown below.

Mass of crucible + hydrated complex  $\bf A$  = 59.554 g Mass of crucible + anhydrous complex  $\bf B$  = 58.690 g Mass of crucible = 51.257 g

The anhydrous complex  $\bf B$  is analysed and found to have a molar mass of 309.7 g mol<sup>-1</sup> and to contain the following percentage composition by mass:

Ni, 18.95%; C, 23.25%; N, 27.12%; H, 7.75%; C*l*, 22.93%.

The anhydrous complex **B** contains a cation **C** comprising Ni, C, N and H only.

Cation  ${\bf C}$  is six-coordinate, contains three molecules of the bidentate ligand  ${\bf D}$ , and exists as optical isomers.

Determine the formula of  ${\bf A},\,{\bf B},\,{\bf C}$  and  ${\bf D}$  and show the 3D structures for the optical isomers of  ${\bf C}.$ 

Show <b>all</b> your working.
[6]

## **END OF QUESTION PAPER**

# 27

# **ADDITIONAL ANSWER SPACE**

If additional space is required, you should use the following lined page(s). The question number(s) must be clearly shown in the margin(s).		




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