

Name Jerry Jiang

31/33

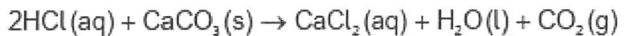
Chem HL 2018-2020
February Mock Exam: Paper 1

Total marks: 33

Time Allowed: 50 minutes

- Do not open the examination paper until instructed to do so
- Answer all the questions
- For each question **circle** the answer you consider to be the best.
 - To correct an answer put a cross through the original and circle your new answer
- Calculators are not allowed
- Data booklets are not allowed
- A Periodic Table is provided at the end of the question booklet

1. 0.10 mol of hydrochloric acid is mixed with 0.10 mol of calcium carbonate.



Which is correct? 0.1 0.05 0.05

	Limiting reagent	Maximum yield of CO_2 / mol
A.	$\text{HCl}(\text{aq})$	0.10
B.	$\text{CaCO}_3(\text{s})$	0.05
C.	$\text{HCl}(\text{aq})$	0.05
D.	$\text{CaCO}_3(\text{s})$	0.10

2. What is the sum of the coefficients when the equation is balanced with whole numbers?



- A. 6
B. 7
C. 8
D. 9

3. Which contains the greatest number of moles of oxygen atoms?

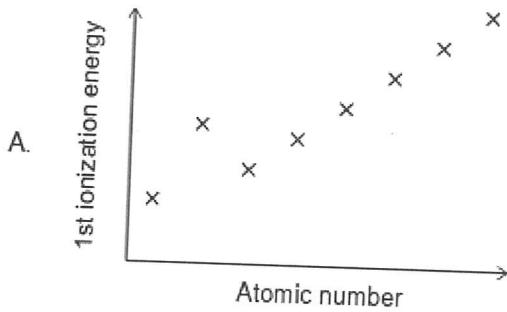
- A. 0.05 mol $\text{Mg}(\text{NO}_3)_2$ 0.3
B. 0.05 mol $\text{C}_6\text{H}_4(\text{NO}_2)_2$ 0.2
C. 0.1 mol H_2O 0.1
D. 0.1 mol NO_2 0.2

4. Which represents the shape of an s atomic orbital?

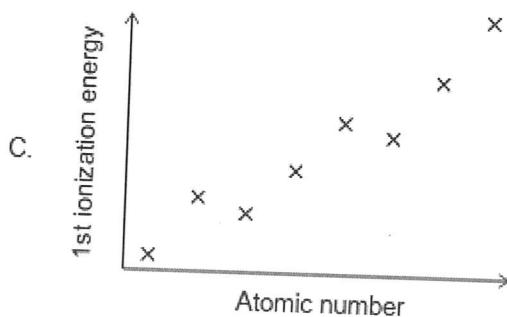
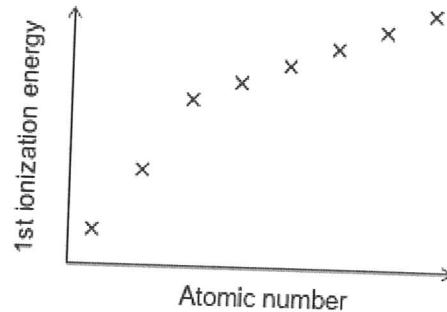
- A.  B. 
C.  D. 

(4)

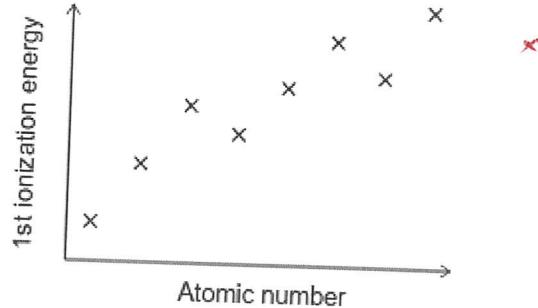
5. Which shows the first ionization energies of successive elements across period 2, from left to right?



B.



D.



6. Which property shows a general increase from left to right across period 2, Li to F?

- A. Melting point
B. Electronegativity
C. Ionic radius
D. Electrical conductivity

7. Which is an f-block element?

- A. Sc
B. Sm
C. Sn
D. Sr

(2)

8. What is the effect of a stronger ligand?

	d-d splitting	Wavelength absorbed
A.	increases	decreases
B.	decreases	decreases
C.	increases	increases
D.	decreases	increases



9. Which compound has the shortest C to O bond?

- A. CH₃CHO
- B. CO
- C. CO₂
- D. C₂H₅OC₂H₅



10. Which describes a resonance structure?

- A. Double bond can be drawn in alternative positions.
- B. Bonds vibrate by absorbing IR radiation.
- C. A double and a single bond in the molecule
- D. A Lewis structure



11. What is the structure and bonding in SiO₂(s)?

	Structure	Bonding
A.	giant	covalent
B.	giant	ionic
C.	bent molecule	covalent
D.	linear molecule	covalent



(4)

12. Which atom is sp^2 hybridized?

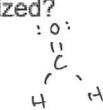
(A)

C in H_2CO

B. C in CO_2

C. N in CH_3NH_2

D. O in H_2O



2p 1 1 1 sp² 1 1 1 1 1

~~✓~~

13. Which atom does **not** obey the octet rule?

A. C in CO_2

B. F in BF_3

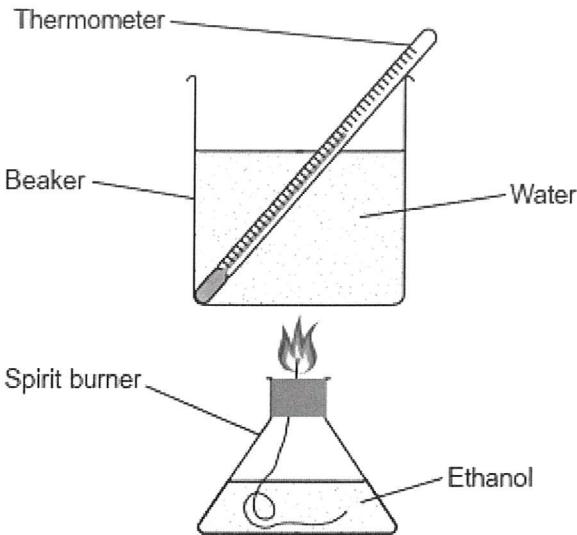
C. O in H_2O

(D)

S in SF_6

~~✓~~

Questions 14 and 15 are about an experiment to measure the enthalpy of combustion, ΔH_c , of ethanol, using the apparatus and setup shown.



(2)

14. What is the enthalpy of combustion, ΔH_c , of ethanol in kJ mol^{-1} ?

Maximum temperature of water: 30.0°C

Initial temperature of water: 20.0°C

Mass of water in beaker: 100.0g

Loss in mass of ethanol: 0.230g

M_r (ethanol): 46.08

Specific heat capacity of water: $4.18\text{J g}^{-1}\text{K}^{-1}$

$$q = mc\Delta T$$

A. $-\frac{100.0 \times 4.18 \times (10.0 + 273)}{\frac{0.230}{46.08} \times 1000}$

$$\begin{aligned} q &= cm\Delta T \\ &= 4.18 \times 10^{-3} \text{ kJ/g/K} \cdot 100 \text{ g} \cdot 10 \text{ K} \end{aligned}$$

B. $-\frac{0.230 \times 4.18 \times 10.0}{\frac{100.0}{46.08} \times 1000}$

$$= \frac{4.18 \cdot 100 \cdot 10}{10^3}$$

C. $-\frac{100.0 \times 4.18 \times 10.0}{\frac{0.230}{46.08} \times 1000}$

$$\begin{aligned} \Delta H_c &= -q/n \\ &= -\frac{4.18 \cdot 100 \cdot 10}{10^3 \cdot \frac{0.23}{46.08}} \end{aligned}$$

D. $-\frac{100.0 \times 4.18 \times 10.0}{\frac{0.230}{46.08}}$

15. Which quantity is likely to be the most inaccurate due to the sources of error in this experiment?

A. Mass of ethanol burnt

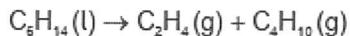
B. Molecular mass of ethanol

C. Mass of water

D. Temperature change

(2)

16. What is the enthalpy change of the reaction?



	Enthalpy of combustion / kJ mol ⁻¹
C ₆ H ₁₄ (l)	-4163
C ₂ H ₄ (g)	-1411
C ₄ H ₁₀ (g)	-2878

$$\begin{array}{rcl}
 \text{C}_6\text{H}_{14} & \rightarrow & -4163 \\
 & \rightarrow \text{C}_2\text{H}_4 & 1411 \\
 & \rightarrow \text{C}_4\text{H}_{10} & 2878
 \end{array}$$

- A. + 1411 + 2878 + 4163
- B. + 1411 - 2878 - 4163
- C. + 1411 + 2878 - 4163
- D. - 1411 - 2878 + 4163



17. Which reaction has the greatest increase in entropy of the system?

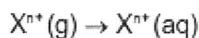
- A. HCl(g) + NH₃(g) → NH₄Cl(s) ↓
- B. (NH₄)₂Cr₂O₇(s) → Cr₂O₃(s) + N₂(g) + 4H₂O(g) ↑
- C. CaCO₃(s) → CaO(s) + CO₂(g) ↕
- D. I₂(g) → I₂(s) ↓



18.

What is the order of increasing (more exothermic) enthalpy of hydration?

Why:



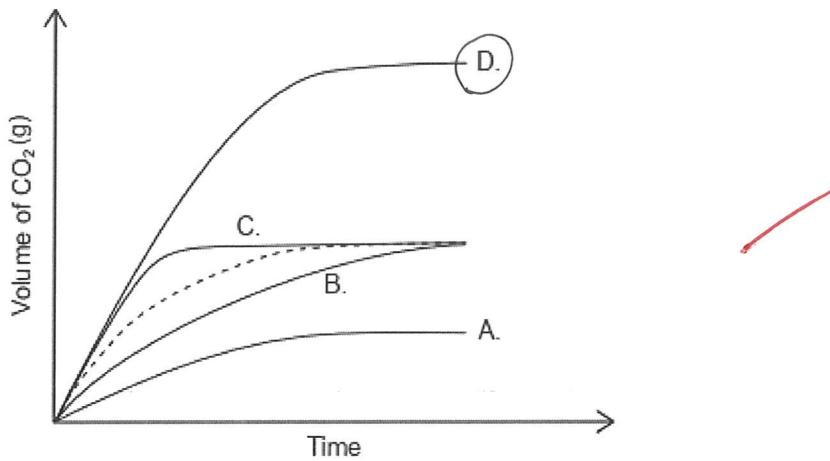
- A. Ca²⁺, Mg²⁺, K⁺, Na⁺
- B. Na⁺, K⁺, Mg²⁺, Ca²⁺
- C. K⁺, Na⁺, Ca²⁺, Mg²⁺
- D. Mg²⁺, Ca²⁺, Na⁺, K⁺



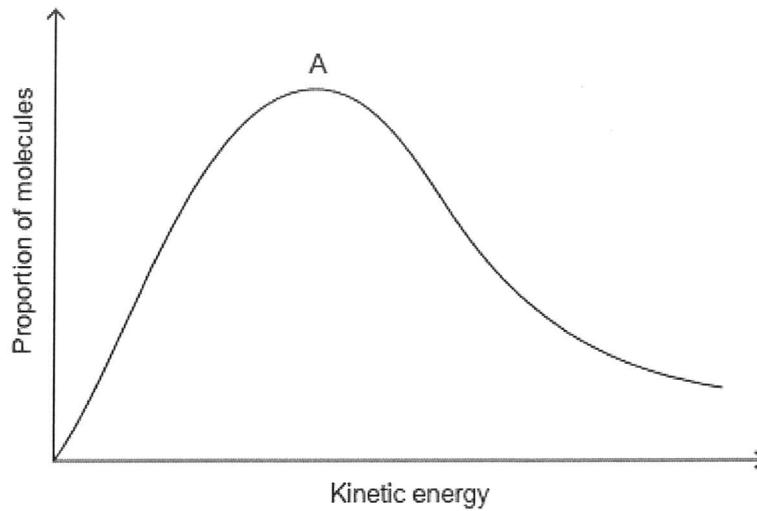
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19. The dotted line represents the volume of carbon dioxide evolved when excess calcium carbonate is added to hydrochloric acid.

Which graph represents the production of carbon dioxide when excess calcium carbonate is added to the same volume of hydrochloric acid of double concentration?



20. The graph shows the Maxwell–Boltzmann energy distribution curve for a given gas at a certain temperature.



How will the curve change if the temperature of the gas is increased, while other conditions remain constant?

- A. The maximum is higher and to the left of A.
- B. The maximum is higher and to the right of A.
- C. The maximum is lower and to the right of A.
- D. The maximum is lower and to the left of A.



(2)

21. Which is correct?

$$\text{M/s} \quad \text{M}^{\cancel{s}} \quad r = k \cdot A^{\cancel{v}} \quad k = \frac{1}{S \cdot M} = \frac{1}{\text{s} \cdot \text{mol}^{-1} \text{dm}^{-3}} = \frac{\text{dm}^3}{\text{s} \cdot \text{mol}^{-1}}$$

	Units of second-order rate constant	Effect of increasing temperature on rate constant
A.	$\text{mol dm}^{-3} \text{s}^{-1}$	increases
B.	$\text{dm}^3 \text{mol}^{-1} \text{s}^{-1}$	increases
C.	$\text{mol dm}^{-3} \text{s}^{-1}$	no change
D.	$\text{dm}^3 \text{mol}^{-1} \text{s}^{-1}$	no change

✓
✗

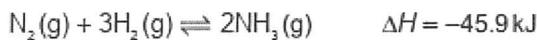
22. What is the intercept on the y-axis when a graph of $\ln k$ is plotted against $\frac{1}{T}$ on the x-axis?

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

- (A) $\ln A$
- B. $-\frac{E_a}{R}$
- C. $-\frac{R}{E_a}$
- D. E_a

✓

23. What effect does increasing both pressure and temperature have on the equilibrium constant, K_c ?



- A. Decreases
- (B) Increases
- C. Remains constant
- D. Cannot be predicted as effects are opposite

✗

24. Which corresponds to a system at equilibrium?

	Entropy	Gibbs free energy
A.	maximum	maximum
(B)	maximum	minimum
C.	minimum	maximum
D.	minimum	minimum

✓

(3)

25. What is the difference between a conjugate Brønsted–Lowry acid–base pair?

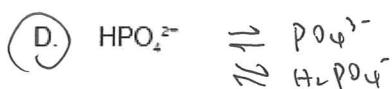
- A. Electron pair
- B. Positive charge

- C. Proton
 D. Hydrogen atom



26. Which is an example of an amphiprotic species?

- A. Al_2O_3
- B. CO_3^{2-}
- C. P_2O_{10}



27. Which can act as a Lewis acid but not a Brønsted–Lowry acid?

- A. BF_3 ✓ ✗
- B. H_2O ✓ ✓
- C. NF_3 ✗ ✗
- D. NH_3 ✓ ✓



28. What is the order, in increasing pH, of the following solutions of equal concentration?

	pKa		Ka
$\text{CH}_3\text{CH}_2\text{CH}_2\text{COOH}$	4.8	CHCl_2COOH	5.0×10^{-2}
$\text{CH}_3\text{CH}_2\text{COOH}$	4.9	H_3BO_3	5.8×10^{-10}

$$\begin{aligned} pK_a & \\ \cancel{\text{H}_3\text{BO}_3} & (-2) \\ \text{H}_3\text{BO}_3 & (-10) \end{aligned}$$

- A. $\text{H}_3\text{BO}_3 < \text{CH}_3\text{CH}_2\text{CH}_2\text{COOH} < \text{CH}_3\text{CH}_2\text{COOH} < \text{CHCl}_2\text{COOH}$
- B. $\text{H}_3\text{BO}_3 < \text{CH}_3\text{CH}_2\text{CH}_2\text{COOH} < \text{CHCl}_2\text{COOH} < \text{CH}_3\text{CH}_2\text{COOH}$
- C. $\text{CH}_3\text{CH}_2\text{CH}_2\text{COOH} < \text{CH}_3\text{CH}_2\text{COOH} < \text{CHCl}_2\text{COOH} < \text{H}_3\text{BO}_3$
- D. $\text{CHCl}_2\text{COOH} < \text{CH}_3\text{CH}_2\text{CH}_2\text{COOH} < \text{CH}_3\text{CH}_2\text{COOH} < \text{H}_3\text{BO}_3$



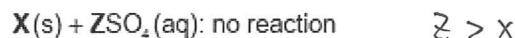
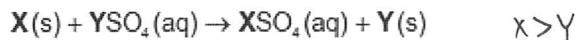
$$\begin{aligned} [\text{HA}] &\approx [\text{A}^-] + [\text{H}^+] \\ K_a &= \frac{[\text{A}^-][\text{H}^+]}{[\text{HA}]} \end{aligned}$$

(4)

29. In which species does sulfur have the same oxidation state as in SO_3^{2-} ?

- A. $\text{S}_2\text{O}_3^{2-}$ +2
 B. SO_4^{2-} +6
 C. H_2S -2
 D. SOCl_2

30. The following occurs when metal X is added to Y sulfate solution and Z sulfate solution.
 (X, Y and Z represent metal elements but not their symbols.)



What is the order of increasing reactivity?

- A. $\text{X} < \text{Y} < \text{Z}$
 B. $\text{Y} < \text{X} < \text{Z}$
 C. $\text{Z} < \text{Y} < \text{X}$
 D. $\text{Z} < \text{X} < \text{Y}$

31. What are the products of electrolysis of concentrated aqueous sodium bromide?

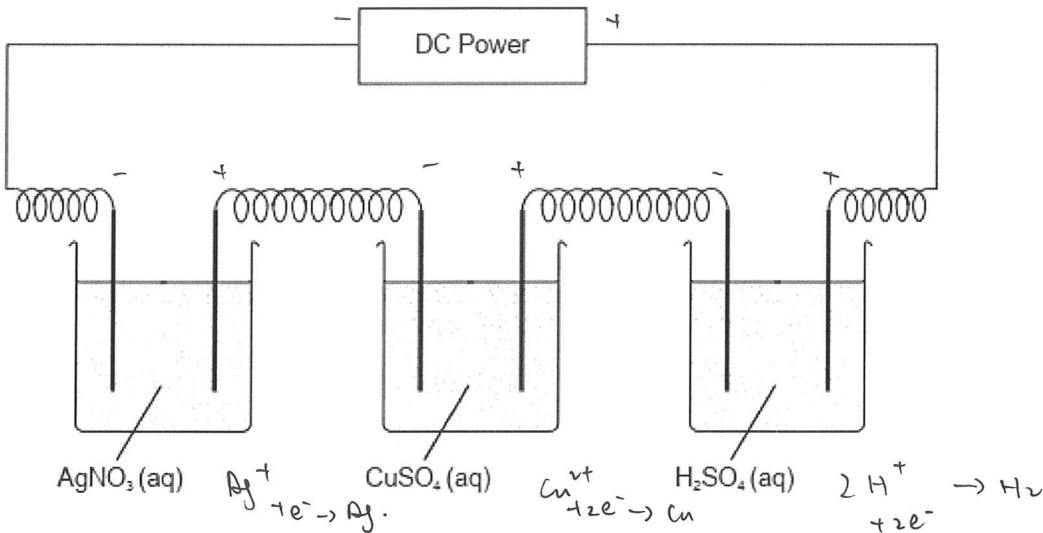
	Positive electrode	Negative electrode
A.	Br_2	Na
B.	O_2	H_2
C.	O_2	Na
D.	Br_2	H_2

NaBr .

+ anode oxidation
 ↓
 - cathode reduction
 ↓

(3)

32. Three cells with platinum electrodes are connected in series to a DC power supply.



What is the ratio of moles formed at each cathode (negative electrode)?

	Ag(s)	Cu(s)	$\text{H}_2(\text{g})$
A.	1	2	1
B.	2	1	1
C.	2	1	2
D.	1	2	2

- 33.

What is the value of the temperature change?

Initial temperature: $2.0 \pm 0.1^\circ\text{C}$

Final temperature: $15.0 \pm 1.0^\circ\text{C}$

- A. $13.0 \pm 0.1^\circ\text{C}$
- B. $13.0 \pm 0.9^\circ\text{C}$
- C. $13.0 \pm 1.0^\circ\text{C}$
- D. $13.0 \pm 1.1^\circ\text{C}$

(2)

Name Jerry Jiang

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Chem HL 2018-2020
February Mock Exam: Paper 2 & Paper 3

Total marks: 64 (P2) + 15 (P3)

Time Allowed: 2 hours

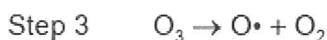
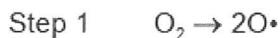
- Do not open the examination paper until instructed to do so
- Answer all the questions
- Answers must be written within the answer boxes provided
- A calculator is required for this paper
- A clean copy of the chemistry data booklet is required for this paper

If this had been the final
"7"

2nd year achieved
"7"

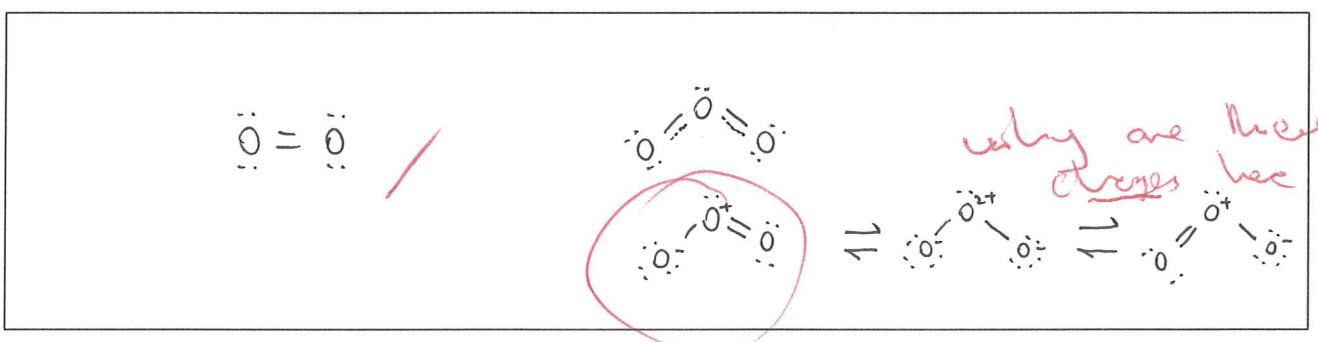
Paper 2

1. The equations show steps in the formation and decomposition of ozone in the stratosphere, some of which absorb ultraviolet light.



- (a) Draw the Lewis structures of oxygen, O_2 , and ozone, O_3 .

[2]



- (b) Outline why both bonds in the ozone molecule are the same length and predict the bond length in the ozone molecule. Refer to section 10 of the data booklet.

[2]

Reason:

...There exists eq resonance structures as in (a).

...The resonance provides identical situation for the two bonds.

Length:

...between $O-O$ and $O=O$, so between 121 pm and 148 pm.

give a value

- (c) Predict the bond angle in the ozone molecule.

[1]

...ozone has bent structure with bond angle a bit less than 120° .

give a value

(4)

(Question 1 continued)

- (d) Discuss how the different bond strengths between the oxygen atoms in O₂ and O₃ in the ozone layer affect radiation reaching the Earth's surface. [2]

O₂ forms free radicals after absorbing ultraviolet radiation with high energy. Then the radicals form O₃ with weaker bonds. The decrease of bond strength takes away certain amount of radiation and less can reach Earth's surface.

O₃ absorbs UV at lower E

- (e) (i) Identify the steps which absorb ultraviolet light. [1]

Step 1 and 3.

- (ii) Determine, showing your working, the wavelength, in m, of ultraviolet light absorbed by a single molecule in one of these steps. Use sections 1, 2 and 11 of the data booklet. [2]

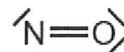
For step 1, the double bond between O atoms is broken.

$$\Delta H = 498 \text{ kJ/mol}$$

$$E = \frac{498 \text{ kJ/mol}}{6.02 \times 10^{23} \text{ mol}} = 8.27 \times 10^{-22} \text{ kJ} = 8.27 \times 10^{-19} \text{ J}$$

$$E = h\nu = h \cdot \frac{c}{\lambda} \quad \lambda = \frac{h \cdot c}{E} = \frac{3.00 \times 10^8 \text{ m/s} \cdot 6.63 \times 10^{-34} \text{ J} \cdot \text{s}}{8.27 \times 10^{-19} \text{ J}} = 2.41 \times 10^{-7} \text{ m}$$

- (f) Ozone depletion is catalysed by nitrogen monoxide, NO, which is produced in aircraft and motor vehicle engines, and has the following Lewis structure.



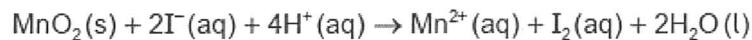
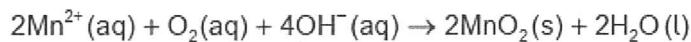
Show how nitrogen monoxide catalyses the decomposition of ozone, including equations in your answer. [2]



NO assists the formation of oxygen radicals to form intermediate NO₂, then NO is regenerated in later reaction between NO₂ and O₃.

6

2. The biochemical oxygen demand of a water sample can be determined by the following series of reactions. The final step is titration of the sample with sodium thiosulfate solution, $\text{Na}_2\text{S}_2\text{O}_3$ (aq).



A student analysed two 300.0 cm^3 samples of water taken from the school pond: one immediately (day 0), and the other after leaving it sealed in a dark cupboard for five days (day 5). The following results were obtained for the titration of the samples with $0.0100 \text{ mol dm}^{-3}$ $\text{Na}_2\text{S}_2\text{O}_3$ (aq).

Sample	Titre / $\text{cm}^3 \pm 0.1 \text{ cm}^3$
Day 0	25.8
Day 5	20.1

- (a) (i) Determine the mole ratio of $\text{S}_2\text{O}_3^{2-}$ to O_2 , using the balanced equations.

[1]



- (ii) Calculate the number of moles of oxygen in the day 0 sample.

[2]

$$\text{N}_{\text{S}_2\text{O}_3^{2-}} = C \cdot V = 0.0100 \text{ M} \cdot 0.0258 \text{ dm}^3 = 2.58 \times 10^{-4} \text{ mol}$$

$$\text{N}_{\text{O}_2} = \frac{1}{4} \text{ N}_{\text{S}_2\text{O}_3^{2-}} = 6.45 \times 10^{-5} \text{ mol}$$

③

(iii) The day 5 sample contained 5.03×10^{-5} moles of oxygen.

Determine the 5-day biochemical oxygen demand of the pond, in mg dm^{-3}
("parts per million", ppm). [2]

For every 0.3000 dm^3 of water in 5 days,

$$6.45 \times 10^{-5} - 5.03 \times 10^{-5} = 1.42 \times 10^{-5} \text{ mol of O}_2 \text{ is consumed}$$
$$\text{5 day BOD} = 1.42 \times 10^{-5} \text{ mol} \times 32.00 \frac{\text{g/mol}}{\text{mol}} \times \frac{1000 \text{ mg/g}}{1 \text{ g}} \div 0.3000 \text{ dm}^3$$
$$= 1.51 \text{ mg/dm}^3$$

(b) (i) Calculate the percentage uncertainty of the day 5 titre. [1]

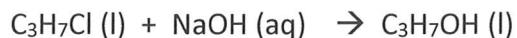
$$\text{percentage uncertainty} = \frac{0.1}{20.1} \times 100\% = 0.50\%$$

(ii) Suggest a modification to the procedure that would make the results more reliable. [1]

Do multiple trials on both day 0 and day 5 to decrease random uncertainty.

(4)

3. (a) 2-Chloropropane (C_3H_7Cl) can be converted to propan-2-ol (C_3H_7OH) by reacting it with aqueous sodium hydroxide;



An experiment was carried out to determine the order of reaction between one of the isomers of C_3H_7Cl and aqueous sodium hydroxide. The following results were obtained.

Experiment	$[C_3H_7Cl] / mol dm^{-3}$	$[OH^-] / mol dm^{-3}$	Initial rate / $mol dm^{-3} s^{-1}$
1	0.05	0.10	3.1×10^{-4}
2	0.10	0.20	1.3×10^{-3}
3	0.15	0.10	9.2×10^{-4}

- (i) Determine the rate expression from the results, explaining your method. [3]

Compare 1 & 3: $[OH^-]$ unchanged, $[C_3H_7Cl] \times 3$, rate $\times 3$.

$[C_3H_7Cl]$ is first order.

Compare 1 & 2: $[C_3H_7Cl] \times 2$, $[OH^-] \times 2$, rate $\approx \times 4$.

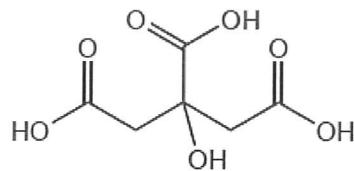
since $[C_3H_7Cl]$ is first order, $[OH^-]$ is first order.

$r = k [C_3H_7Cl] [OH^-]$, take in data in 1 to get $k = 0.062 s^{-1} m^{-1}$

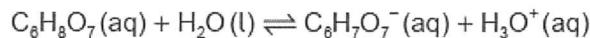
Thus, $r = 0.062 [C_3H_7Cl] [OH^-]$.

(3)

4. A molecule of citric acid, $C_6H_8O_7$, is shown.



The equation for the first dissociation of citric acid in water is



- (a) (i) Identify a conjugate acid–base pair in the equation. [1]

conjugate acid : $C_6H_7O_7^-$

conjugate base : $C_6H_8O_7$

- (ii) The value of K_a at 298 K for the first dissociation is 5.01×10^{-4} .

State, giving a reason, the strength of citric acid. [1]

K_a is small, which means left side is preferred.
Not a lot of citric acid can be converted so it's strong.
What is dole of strong acid?

- (iii) The dissociation of citric acid is an endothermic process. State the effect on the hydrogen ion concentration, $[H^+]$, and on K_a of increasing the temperature. [2]

Effect on $[H^+]$	Effect on K_a
increase	increase

- (iv) Calculate the standard Gibbs free energy change, ΔG^\ominus , in kJ mol^{-1} , for the first dissociation of citric acid at 298 K, using section 1 of the data booklet. [1]

$$\begin{aligned}\Delta G^\ominus &= -RT\ln K = -8.31 \text{ J K}^{-1} \text{ mol}^{-1} \cdot 298 \text{ K} \cdot \ln 5.01 \times 10^{-4} \\ &= 1.88 \times 10^4 \text{ J/mol} \\ &= 18.8 \text{ kJ/mol.}\end{aligned}$$

(4)

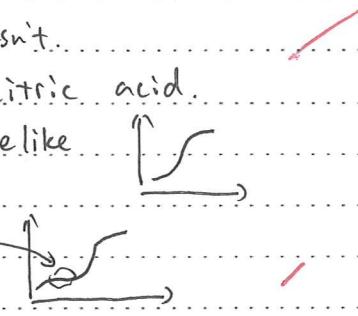
(v) Comment on the spontaneity of the reaction at 298K.

[1]

$\Delta G^\circ > 0$, non-spontaneous

(b) Outline **two** laboratory methods of distinguishing between solutions of citric acid and hydrochloric acid of equal concentration, stating the expected observations.

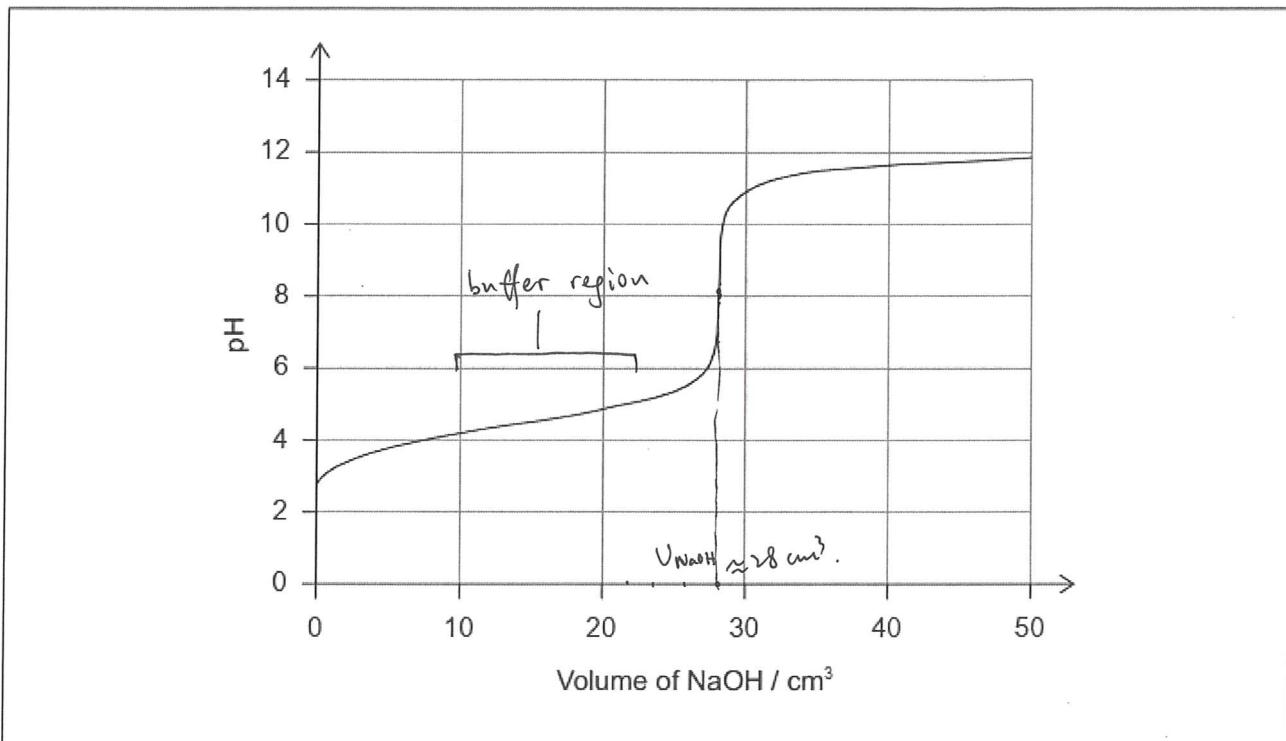
[2]

- ① HCl fully dissociates while citric acid doesn't.
the pH of HCl should be lower than citric acid.
 - ② titrate with NaOH: HCl graph should be like
- while citric acid has a buffer region.
- 

③

5. Another common acid found in food is ethanoic acid.

- (a) A sample of ethanoic acid was titrated with sodium hydroxide solution, and the following pH curve obtained.



Annotate the graph to show the buffer region and the volume of sodium hydroxide at the equivalence point.

[2] 2

- (b) (i) Identify the most suitable indicator for the titration using section 22 of the data booklet.

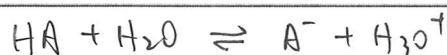
[1]

... Phenolphthalein :

1

- (ii) Describe, using a suitable equation, how the buffer solution formed during the titration resists pH changes when a small amount of acid is added.

[2]



when H_3O^+ is increased, the equilibrium shifts to the left, minimizing influence of the acid.

Need to relate to the acid/base in the title!

(4)

6. Copper forms two chlorides, copper(I) chloride and copper(II) chloride.

- (a) (i) State the electron configuration of the Cu^+ ion.

[1]

[Ar] $3d^0$.

- (ii) Copper(II) chloride is used as a catalyst in the production of chlorine from hydrogen chloride.



Calculate the standard enthalpy change, ΔH^\ominus , in kJ, for this reaction, using section 12 of the data booklet.

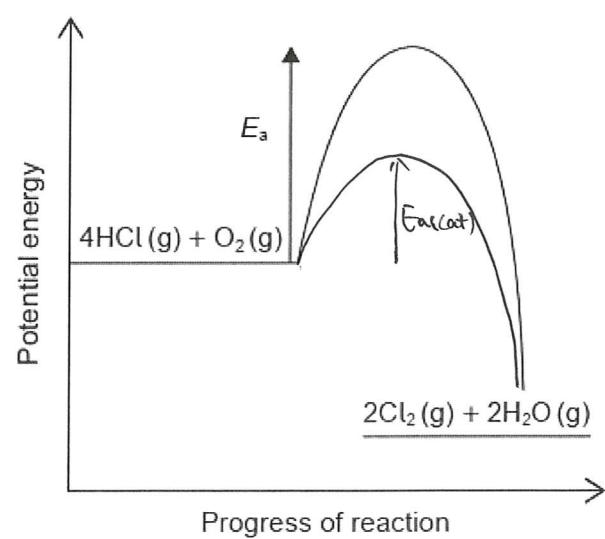
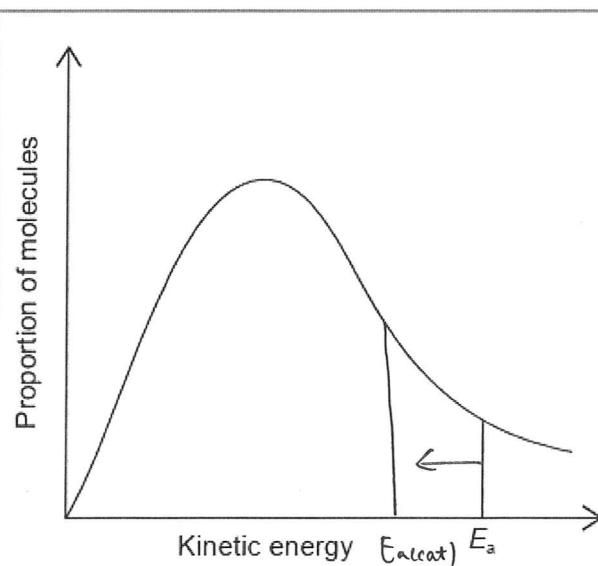
[2]

$$\begin{aligned}\Delta H^\ominus &= 2 \Delta H_f^\ominus \text{H}_2\text{O}(g) - 4 \Delta H_f^\ominus \text{HCl}(g) \\ &= 2 \times (-241.8) - 4 \times (-92.3) \text{ kJ/mol} \\ &= -114.4 \text{ kJ/mol}\end{aligned}$$

- (iii) The diagram shows the Maxwell–Boltzmann distribution and potential energy profile for the reaction without a catalyst.

Annotate both charts to show the activation energy for the catalysed reaction, using the label $E_{a(\text{cat})}$.

[2]



5

(iv) Explain how the catalyst increases the rate of the reaction.

[2]

It provides an alternative pathway of the reaction and decrease the activation energy.
Since $k = A e^{-\frac{E_a}{RT}}$, $E_a \downarrow$, $k \uparrow$, rate increases accordingly.

2

- (b) Solid copper(II) chloride absorbs moisture from the atmosphere to form a hydrate of formula $\text{CuCl}_2 \cdot x\text{H}_2\text{O}$.

A student heated a sample of hydrated copper(II) chloride, in order to determine the value of x . The following results were obtained:

Mass of crucible = 16.221 g

Initial mass of crucible and hydrated copper(II) chloride = 18.360 g

Final mass of crucible and anhydrous copper(II) chloride = 17.917 g

Determine the value of x .

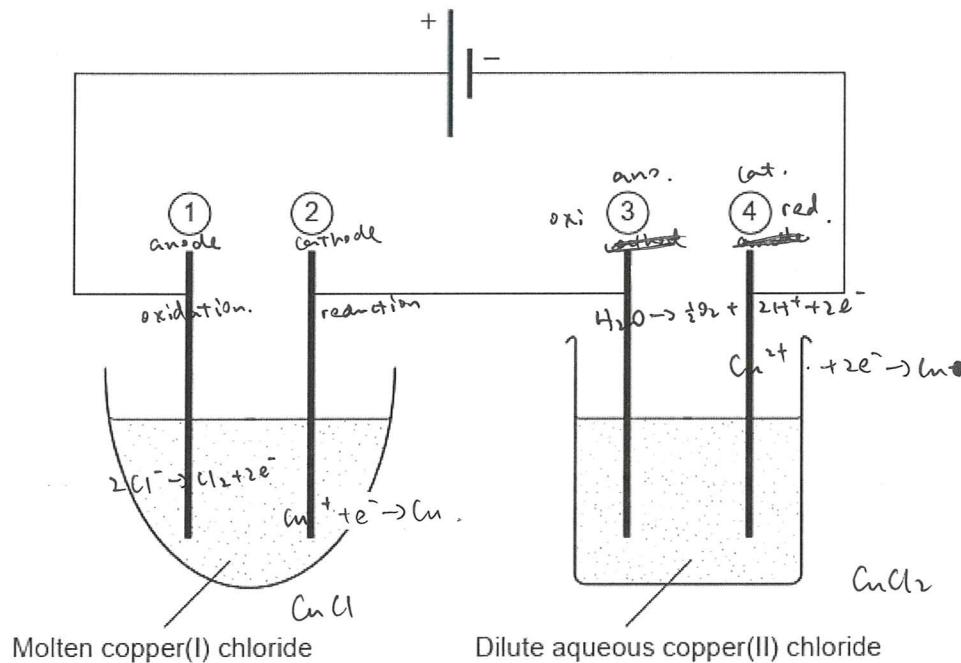
[3]

$$\begin{aligned} M_{\text{CuCl}_2} &= 17.917 \text{ g} - 16.221 \text{ g} = 1.696 \text{ g} \\ M_{x\text{H}_2\text{O}} &= 18.360 \text{ g} - 17.917 \text{ g} = 0.443 \text{ g} \\ n_{\text{CuCl}_2} &= 1.696 \text{ g} \div (63.55 + 2 \times 35.45) \text{ g/mol} = 0.0126 \text{ mol} \\ n_{x\text{H}_2\text{O}} &= 0.443 \text{ g} \div (1.01 \times 2 + 16.00) \text{ g/mol} = 0.0246 \text{ mol} \\ n_{x\text{H}_2\text{O}} &\approx 2 n_{\text{CuCl}_2} \\ \text{So } x &\approx 2 \end{aligned}$$

3

(B)

- (c) Two electrolysis cells were assembled using graphite electrodes and connected in series as shown.

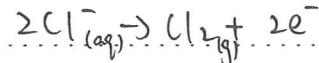


- (i) State how current is conducted through the wires and through the electrolyte. [2]

Wires: wires are made of metal with cations and delocalized electron sea, allowing e^- travel from ④ to ①, ③ → ② return from ① to +. Current goes the opposite way from + → ①, then ② → ③, finally ④ → ①. passage of e^- .

Electrolyte: electrolyte is rich in ions and allows passage of e^- .
Wires move

- (ii) Write the half-equation for the formation of gas bubbles at electrode 1. [1]



(2)

- (iii) Bubbles of gas were also observed at another electrode. Identify the electrode and the gas.

[1]

Electrode number (on diagram):

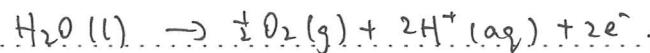
③

Name of gas:

O₂

- (iv) Deduce the half-equation for the formation of the gas identified in (c)(iii).

[1]

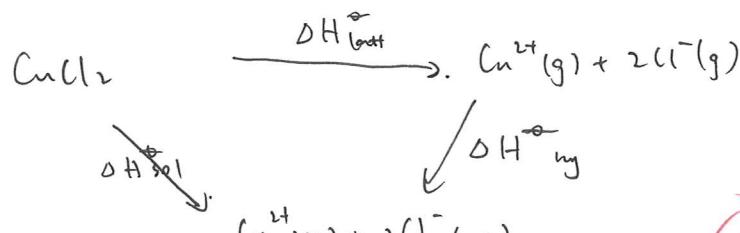


- (d) Determine the enthalpy of solution of copper(II) chloride, using data from sections 18 and 20 of the data booklet.

The enthalpy of hydration of the copper(II) ion is -2161 kJ mol⁻¹.

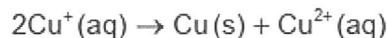
[2]

$$\begin{aligned}\Delta H_{\text{sol}}^\ominus &= 2824 \text{ kJ/mol} + (-2161 \text{ kJ/mol}) + 2 \times (-359 \text{ kJ/mol}) \\ &= -55 \text{ kJ/mol.}\end{aligned}$$



④

- (e) Copper(I) chloride undergoes a disproportionation reaction, producing copper(II) chloride and copper.



- (i) Calculate the cell potential at 298K for the disproportionation reaction, in V, using section 24 of the data booklet.

[1]

$$E^\ominus = -0.15 + 0.52 = 0.37\text{V}$$

- (ii) Comment on the spontaneity of the disproportionation reaction at 298 K.

[1]

$E^\ominus > 0$, $\Delta G^\ominus < 0$, spontaneous.

- (iii) Calculate the standard Gibbs free energy change, ΔG^\ominus , to two significant figures, for the disproportionation at 298K. Use your answer from (e)(i) and sections 1 and 2 of the data booklet.

[1]

$$\begin{aligned}\Delta G^\ominus &= -nFE^\ominus \\ &= (2\text{ mol}) \cdot 9.65 \times 10^4 \text{ C/mol} \cdot 0.37\text{V} \\ &= -7.1 \times 10^4 \text{ J}\end{aligned}$$

Only 1 e⁻ in oxidation/reducⁿ reaction.

- (iv) Suggest, giving a reason, whether the entropy of the system increases or decreases during the disproportionation.

[1]

entropy decrease as solid contain increase and disorder in solution decreases.

3

- (v) Deduce, giving a reason, the sign of the standard enthalpy change, ΔH° , for the disproportionation reaction at 298 K.

[1]

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

$\Delta G^\circ < 0$, $\Delta S^\circ < 0$, $-T\Delta S^\circ > 0$, so ΔH° must be negative.

- (vi) Predict, giving a reason, the effect of increasing temperature on the stability of copper(I) chloride solution.

[1]

$\Delta H^\circ < 0$, it shifts equilibrium

$\Delta G = \Delta H - TS$ How does this affect ΔG change with T

- (f) Dilute copper(II) chloride solution is light blue, while copper(I) chloride solution is colourless.

- (i) Describe how the blue colour is produced in the Cu(II) solution. Refer to section 17 of the data booklet.

H_2O acts as ligand and bind to Cu^{2+} , so

Cu^{2+} has $[Ar] 3d^9$ which is partially filled d orbitals

split by ligands to produce a energy gap that absorbs orange light around 600 nm, the blue light that passes provides the color of the solution.

④

- (iii) When excess ammonia is added to copper(II) chloride solution, the dark blue complex ion, $[\text{Cu}(\text{NH}_3)_4(\text{H}_2\text{O})_2]^{2+}$, forms.

State the molecular geometry of this complex ion, and the bond angles within it. [1]

Molecular geometry:

..... octahedral

Bond angles:

..... 90° and 180°

- (iv) Examine the relationship between the Brønsted-Lowry and Lewis definitions of a base, referring to the ligands in the complex ion $[\text{CuCl}_4]^{2-}$. [2]

B-L base: accepting H^+ : Cl^- is a Lewis base
but not BL.

L base: donating electron pairs.

Cu^{2+} is accepting e^- pairs, act as Lewis base

but it doesn't act as Bronsted-Lowry base in this case.

All Bronsted-Lowry base are Lewis base but not the converse.

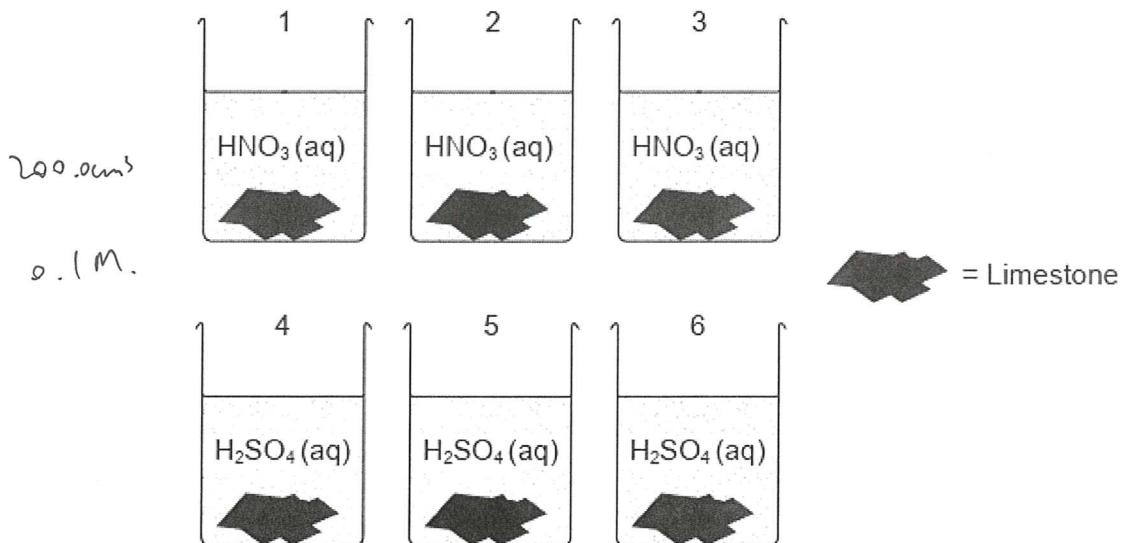
(2)

Paper 3

1. A student investigated how the type of acid in acid deposition affects limestone, a building material mainly composed of calcium carbonate.

	Solubility
calcium carbonate	insoluble
calcium nitrate	soluble
calcium sulfate	slightly soluble

The student monitored the mass of six similarly sized pieces of limestone. Three were placed in beakers containing 200.0 cm^3 of 0.100 mol dm^{-3} nitric acid, $\text{HNO}_3\text{(aq)}$, and the other three in 200.0 cm^3 of 0.100 mol dm^{-3} sulfuric acid, $\text{H}_2\text{SO}_4\text{(aq)}$.

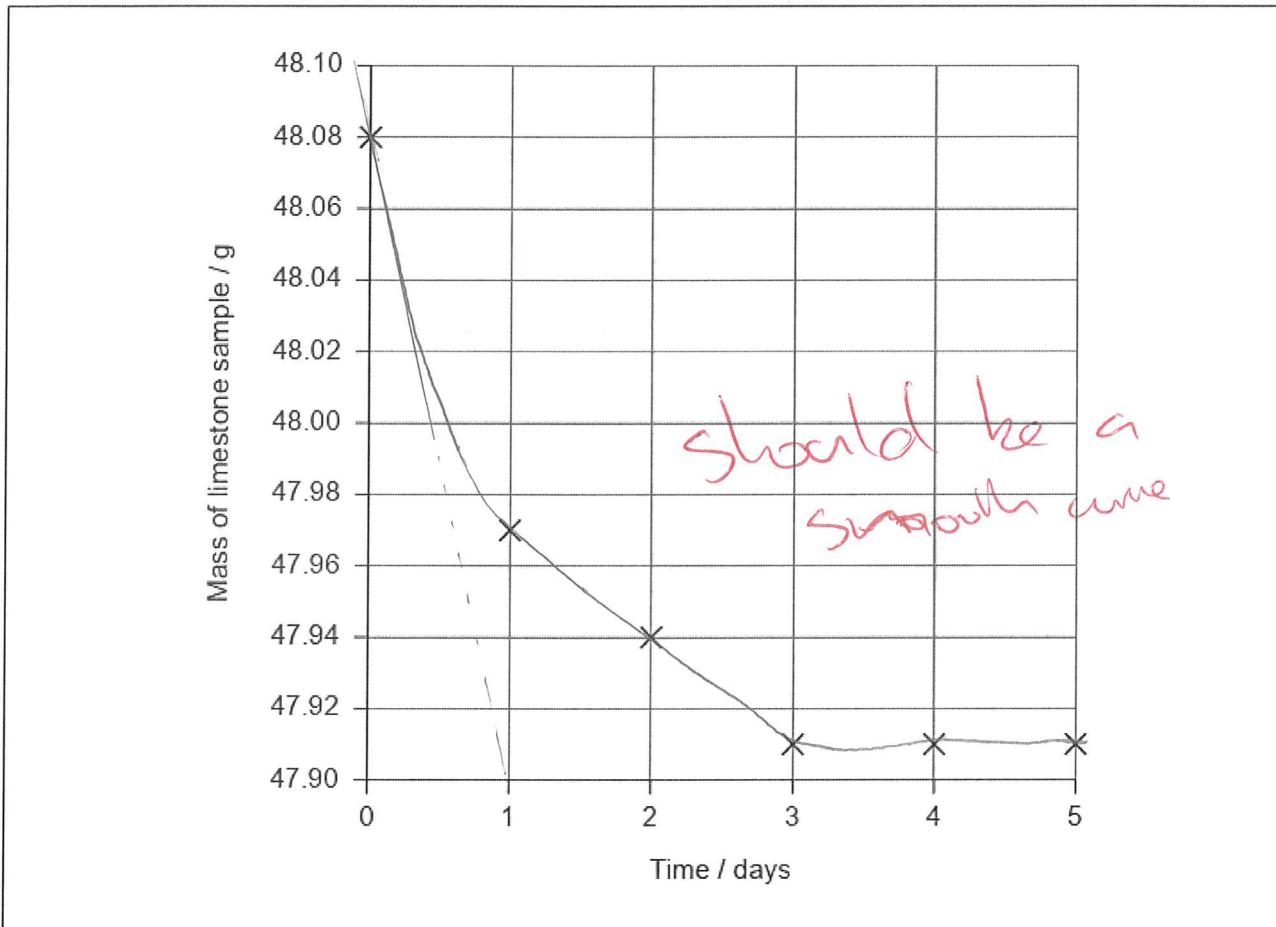


(This question continues on the following page)

(Question 1 continued)

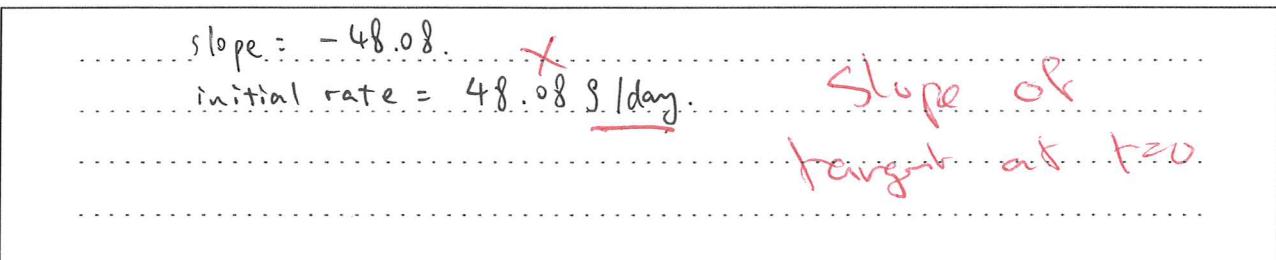
The limestone was removed from the acid, washed, dried with a paper towel and weighed every day at the same time and then replaced in the beakers.

The student plotted the mass of one of the pieces of limestone placed in nitric acid against time.



- (a) Draw a best-fit line on the graph. [1]

- (b) (i) Determine the initial rate of reaction of limestone with nitric acid from the graph. Show your working on the graph and include the units of the initial rate. [3]



(2)

(Question 1 continued)

- (ii) Explain why the rate of reaction of limestone with nitric acid decreases and reaches zero over the period of five days.

[2]

Nitric acid is used up after day 3, so mass is unchanged.
Before that $[H^+]$ is decreased, so the rate decrease as well.
i.e. HNO_3 is limiting.
Why does rate decrease? (collisions...)

- (iii) Suggest a source of error in the procedure, assuming no human errors occurred and the balance was accurate.

[1]

Stone not fully dried when weighed.
Stone brings out acid from beaker and reduce amount of acid available.

- (c) The student hypothesized that sulfuric acid would cause a larger mass loss than nitric acid.

- (i) Justify this hypothesis.

[1]

With the same number of moles, $[H^+]$ in H_2SO_4 is twice compared to $[HNO_3]$, providing more acid available to react with the stone.

- (ii) The student obtained the following total mass losses.

Acid	Nitric acid			Sulfuric acid		
	1	2	3	4	5	6
Limestone sample						
Total mass loss / g	0.17	0.14	0.15	0.10	0.07	0.08

She concluded that nitric acid caused more mass loss than sulfuric acid, which did not support her hypothesis.

Suggest an explanation for the data, assuming that no errors were made by the student.

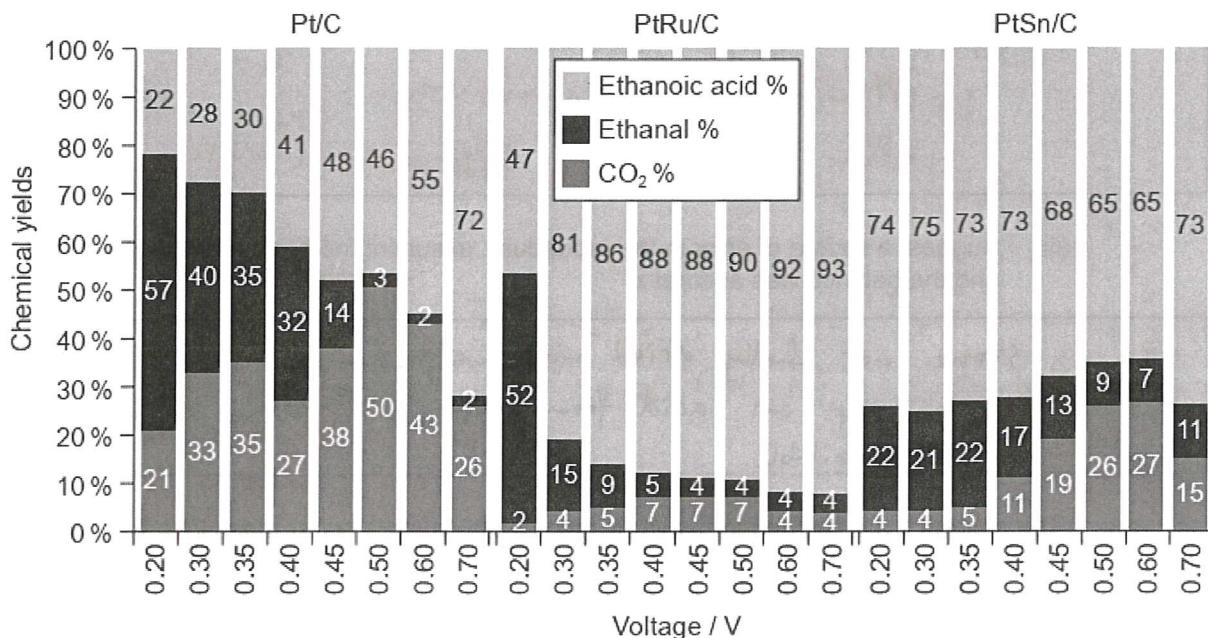
[1]

When H_2SO_4 react with lime stone, insoluble $CaSO_4$ is formed on the stone and prevent further reaction.

②

2. Ethanol was electrolysed at different voltages. The products at the anode, ethanoic acid, ethanal and carbon dioxide, were collected and analysed.

The percentages of products obtained using three different catalysts mounted on a carbon anode, platinum (Pt/C), platinum and ruthenium alloy (PtRu/C) and platinum and tin alloy (PtSn/C) are shown.



Chemical yields of ethanoic acid, ethanal and carbon dioxide as a function of voltage for oxidation of $0.100 \text{ mol dm}^{-3}$ ethanol at Pt/C, PtRu/C and PtSn/C anodes at 80°C .

[Source: <http://jes.ecsdl.org>]

- (a) (i) Describe the effect of increasing the voltage on the chemical yield of: [2]

Ethanal using Pt/C:

Ethanal % has a general trend of decrease.

Carbon dioxide using PtRu/C:

~~CO₂ % first increase to 7% around 0.4 - 0.5V then decrease at 0.6 - 0.7V.~~

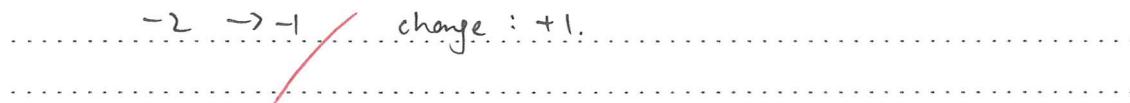
(2)



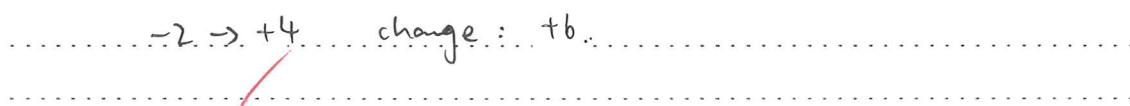
(ii) Determine the change in the average oxidation state of carbon.

[2]

From ethanol to ethanal:



From ethanol to carbon dioxide: CO_2 .



(iii) List the three products at the anode from the least to the most oxidized.

[1]



(b) Deduce, giving your reason, which catalyst is most effective at fully oxidizing ethanol.

[1]

Pt / C is most efficient as $\text{O}_2^{+/-}$ is the highest among the three. (O_2 is the most oxidized state).

4