

Unit exam with answers

Unit 3 Equilibrium, acids and bases and redox reactions

Time permitted: 70 minutes

	Section	Number of questions	Marks available
A	Multiple choice	30	30
B	Short answer	10	40
	Total		70

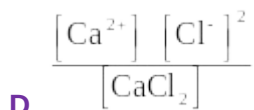
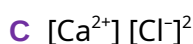
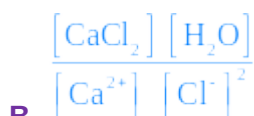
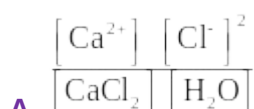
Scale:

A+	66–70	A	60–65	B	50–59	C	40–49	D	35–39	E	21–34	UG	0–20
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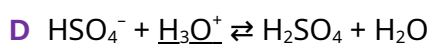
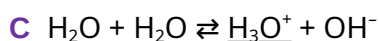
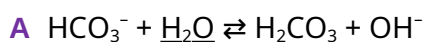
Section A Multiple choice (30 marks)

Section A consists of 30 questions, each worth one mark. Each question has only one correct answer. Circle the correct answer. Attempt all questions. Marks will not be deducted for incorrect answers. You are advised to spend no more than 30 minutes on this section.

- 1 What is the equilibrium expression for dissolving solid calcium chloride?



- 2 In which of the following equilibria does the underlined act as a base?

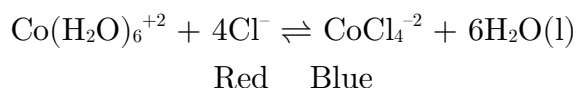


- 3 Element Q has the following six successive ionisation energies (in kJ mol⁻¹).

589.8; 1145.4; 4912.4; 6491; 8153; 10 496

What will be the formula of a compound when it reacts with fluorine?

- A QF
 - B Q_2F
 - C QF_2
 - D Q_2F
- 4 The equilibrium quotient, K, will be the same as the reaction quotient, Q, at equilibrium. Which of the following is also correct?
- A $Q > K$, then there are more products than reactants.
 - B $Q > 1$, then there are more reactants than products.
 - C $Q < K$, then there are less products than reactants.
 - D $K < 1$, then there are more products than reactants.
- 5 Cobalt chloride dissolves in dilute hydrochloric acid to form an equilibrium.



The red and blue colours mix to form a purple solution. What change will cause a redder solution to form?

- A The addition of a catalyst
 - B Adding a few drops of concentrated HCl
 - C Adding few millilitres of silver nitrate solution
 - D The addition of water
- 6 A student carries out a titration and obtains the following results.

Final reading (mL)	23.10	22.55	22.60	22.00	22.40
Initial reading (mL)	0.10	1.00	1.10	1.65	0.85

What titration figure should she use in her subsequent calculation?

- A 21.24 mL
 - B 21.59 mL
 - C 21.53 mL
 - D 21.35 mL
- 7 Which of the following oxides would be acidic?
- A Na_2O
 - B MgO
 - C Al_2O_3
 - D CO
- 8 Which one of the following, when diluted, is a weak electrolyte?
- A $\text{Ca}(\text{OH})_2$
 - B HNO_3

C CH_3COOH

D NaOH

9 What is the pH of a 2 mol L^{-1} solution of Ca(OH)_2 ?

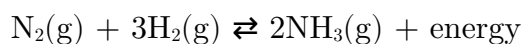
A 0.3

B 0.6

C 13.4

D 13.7

10 A reaction can be sped up in several ways. Which method from the list below would *not* affect the rate of reaction?



i Temperature change

ii Pressure change

iii Adding a catalyst

iv Adding more reactants

A i only

B i and ii

C *iv only*

D None of the above

11 Successive ionisation energies can determine which group an element belongs to. To which group does this element belong?

First	787 kJ mol^{-1}
Second	1577 kJ mol^{-1}
Third	3232 kJ mol^{-1}
Fourth	4356 kJ mol^{-1}
Fifth	$16\,091 \text{ kJ mol}^{-1}$

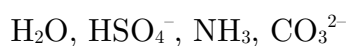
A 2

B 13

C 14

D 15

12 Which is a correct conjugate pairing of the following, in order?



A OH^- , H_2SO_4 , NH_4^+ , CO_2

B H_3O^+ , HSO_4^{--} , NH_2 , HCO_3^-

C OH^- , SO_4^{2-} , NH_4^+ , HCO_3^-

D H_3O^+ , SO_4^{2-} , NH_4^+ , H_2CO_3

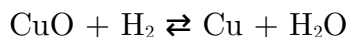
13 In an equilibrium reaction:

A the amount of reactants and products are the same.

- B** products will not form if reactants are favoured.
- C** all reactants become products.
- D** *the rate of forward and reverse reactions are the same.*
- 14** What is the pH of a 5 mol L^{-1} solution of HCl?
- A** 12.5
- B** 0.5
- C** 0.7
- D** *1.4*
- 15** Which of the following are in order of increasing ionisation energy?
- A** *Be, B, C, N, O, F*
- B** F, O, N, C, B, Be
- C** B, Be, C, O, F, N
- D** N, O, F, Be, B, C
- 16** Which of the following statements is *not* true?
- A** Bases are cations, anions or molecules that donate protons to other species.
- B** The ability to accept protons from other species is a property of bases.
- C** *A base is produced when a cation, anion or molecule donates a proton.*
- D** When a proton is donated by one species to another, it is an acid–base reaction.
- 17** The K_w of water at 50°C is 5.476×10^{-14} . What is pH of water at this temperature?
- A** *6.6*
- B** 7.0
- C** 7.4
- D** 3.2
- 18** In which group would all three oxides be classified as acidic oxides?
- A** CO_2 , SiO_2 , CuO
- B** Na_2O , SiO_2 , CO_2
- C** *SO_2 , NO_2 , SO_3*
- D** CaO , SO_2 , SO_3
- 19** Which of the following reactions would *not* change when the pressure changed?
- A** $\text{N}_2(\text{g}) + 3\text{H}_2(\text{g}) \rightleftharpoons 2\text{NH}_3(\text{g})$
- B** $\text{N}_2(\text{g}) + \text{O}_2(\text{g}) \rightleftharpoons 2\text{N}_2\text{O}(\text{g})$
- C** *$\text{N}_2(\text{g}) + \text{O}_2(\text{g}) \rightleftharpoons 2\text{NO}(\text{g})$*
- D** $\text{N}_2\text{O}_4(\text{g}) \rightleftharpoons 2\text{NO}_2(\text{g})$
- 20** Which one of the following compounds is a triprotic acid?
- A** Sulfuric acid
- B** Ammonia
- C** Nitric acid

D *Phosphoric acid*

21 Which is true for the following reaction?



A CuO is a reductant.

B H₂O is the reductant.

C Cu is the oxidant.

D *H₂ is oxidised.*

22 Which is the correct equilibrium reaction for this equilibrium constant expression?

$$K = \frac{[\text{NOCl}]^2}{[\text{NO}]^2 [\text{Cl}_2]}$$

A Cl₂ + NO \rightleftharpoons NOCl

B 2NOCl \rightleftharpoons Cl₂ + 2NO

C *NOCl \rightleftharpoons Cl₂ + NO*

D Cl₂ + 2NO \rightleftharpoons 2NOCl

23 Which of the following is false for equilibrium?

A The speed of product formation is equivalent to the speed of reactant formation.

B It never ceases.

C *Concentrations of all species are equal.*

D Concentrations are unchanging.

24 Water is not included in equilibrium expressions. Which answer does *not* explain this?

A It is constant.

B Its concentration is unchanging.

C *It plays no part in facilitating the reaction.*

D It is a spectator.

25 In electrochemical cells, the salt bridge:

A *completes the circuit by allowing the ions to move between the two half-cells.*

B completes the circuit by allowing electrons to move between the two half-cells.

C completes the circuit by allowing a current to flow from the anode to the cathode.

D completes the circuit by allowing a current to flow from the cathode to the anode.

26 When titrating, what should the burette be rinsed with?

A *Distilled water*

B Dilute acid

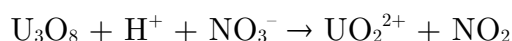
C Solution to be pipetted

- D** Dilute alkali
- 27** What should a conical flask used in titration be rinsed with?
- A** *Distilled water*
- B** Dilute acid
- C** Solution to be pipetted
- D** Dilute alkali
- 28** Which indicator would you use for titrating dilute potassium hydroxide (0.01 mol L^{-1}) and dilute ethanoic acid (0.01 mol L^{-1})?
- A** Methyl orange (pH range: 3.1–4.4)
- B** Methyl red (pH range: 4.4–6.2)
- C** Bromothymol blue (pH range: 6.0–7.6)
- D** *Phenolphthalein (pH range: 8.3–10.0)*
- 29** Methanol can be made as follows:
- $$\text{CO(g)} + 2\text{H}_2\text{(g)} \rightleftharpoons \text{CH}_3\text{OH(g)} + \text{heat}$$
- How would you increase product?
- A** Increase the temperature.
- B** *Decrease the temperature.*
- C** Reduce the $[\text{CO}]$.
- D** Reduce the pressure.
- 30** In order of electronegativity, first ionisation energy and atomic size, what are the trends in group 1?
- A** Decreases; decreases; decreases
- B** Decreases; increases; increases
- C** *Decreases; decreases; increases*
- D** Increases; decreases; decreases

Section B Short answer (40 marks)

Section B consists of 10 questions. Write your answers in the space provided. You are advised to spend 40 minutes on this section.

- 1** Pitchblende, U_3O_8 , is a naturally occurring ore of uranium. The following reaction occurs when the ore is processed:

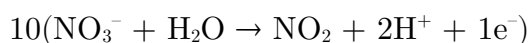


- a** Balance this redox reaction.

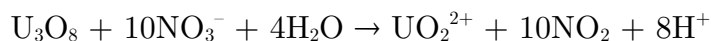
Answer:



(1 mark)



(1 mark)



(1 mark)

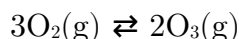
- b** Calculate the oxidation number of U in UO_2^{2+} . (Show your working.)

Answer: O is -2 so two O = -4, and the overall charge is + 2 + 2 = -4 + 6. Hence O.N on U is +6.

(1 mark)

(= 4 marks total)

- 2** For the following endothermic reaction, list all the ways to decrease the product and increase the reactant species.



Answer: You can increase the volume; decrease pressure; decrease temperature and/or remove oxygen.

(1 mark)

You can increase the amount of reactants and decrease the products by increasing the volume of the container; this decreases the pressure. The equilibrium will want to increase the moles of gases to increase pressure to minimise the change. So it shifts to the left to increase the moles of O_2 , decreasing moles of O_3 .

(1 mark)

You can decrease the temperature; because the forward reaction is endothermic, reducing the temperature will shift the equilibrium in the exothermic (reverse) direction to minimise the imposed change. This will decrease the amount of product O_3 and increase the amount of reactant, O_2 .

(1 mark)

Removing O_2 itself, by an undisclosed method, will result in the same effect, the equilibrium will reverse to produce more O_2 to minimise the change, until it re-establishes a new equilibrium.

(1 mark)

(= 4 marks total)

- 3 a** What are the main trends in atomic radius?

Answer: Across a period atomic radius decreases across and up the table. This decreases, moving right across the period as the increased nuclear charge increasingly attracts the valence electrons.

(1 mark)

- b** Explain the trends across a row in the periodic table and down a group.

Answer: The increase down the group occurs as the outer electron(s) are in energy levels that are further and further away from the nucleus.

(2 marks)

(= 3 marks total)

- 4** For each of the following reactions, predict what will occur when the imposed change occurs.

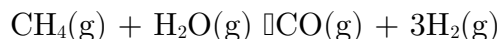
- a** Sodium ethanoate is added to:



Answer: The amount of molecular ethanoic acid will increase. Sodium ethanoate ion into the equilibrium solution dissociates releasing CH_3COO^- ions, so equilibrium will adjust to minimise the change by shifting to the left.

(1 mark)

b Pressure is increased on:

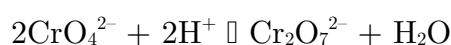


Answer: Equilibrium shifts to the left. The amount of CO and H_2 will decrease and CH_4 and H_2O increase.

Increasing pressure will cause equilibrium to shift to minimise the effect of the increasing pressure by reducing the amount of gases. The left side has 2 mol of gases; the right has 4 mol of gases.

(1 mark)

c Acid is added to:



Answer: Adding acid will shift equilibrium to the right to reduce the amount of the added H^+ ions released by the acid.

(1 mark)

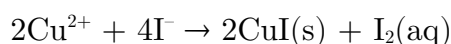
d Describe the colour change that would occur for the above reaction if the chromate ions are yellow and dichromate ions are orange.

Answer: Chromate ions (CrO_4^{2-}) are yellow and dichromate ions are orange. So the solution will also change colour, becoming more orange.

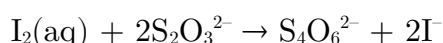
(1 mark)

(= 4 marks total)

5 The amount of copper in a solution of a copper(II) salt can be determined by reacting it with an excess of an iodide solution, described by the balanced oxidation-reduction equation below:



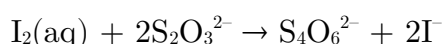
The resulting iodine solution is then titrated with thiosulphate as shown in the balanced oxidation-reduction equation:



In an analysis, 0.245 g of a copper salt produced a solution of iodine which required 24.8 mL of thiosulphate solution (0.060 mol L^{-1}) to reach an endpoint.

a Calculate the number of moles of iodine formed.

Answer: Using the second equation:



We see the molar ratio of I_2 : $\text{S}_2\text{O}_3^{2-}$ is 1:2; i.e. every mole of thiosulfate reacts with half a mole of iodine. We calculate the moles of thiosulfate and halve it to find the moles of iodine that react.

$$n = cv$$

$$n_{\text{S}_2\text{O}_3^{2-}} = (0.060)(24.8 \times 10^{-3}) = 0.001488 \text{ mol of thiosulfate reacted.}$$

$$n(\text{I}_2) = \frac{1}{2} \times n n_{\text{S}_2\text{O}_3^{2-}} = 7.44 \times 10^{-4} \text{ mol} \quad (2 \text{ marks})$$

- b** Calculate the number of moles of copper(II) ions that reacted with the iodide solution.

Answer: $n_{\text{Cu}^{2+}}$ that reacted is calculated by looking at the first equation. $\text{Cu}^{2+}:\text{I}_2$ is 2:1; i.e. for every mole of iodine there are two moles of copper ions.

$$n_{\text{Cu}^{2+}} = 2 \times n(\text{I}_2) = 1.488 \times 10^{-3} \text{ mol} \quad (2 \text{ marks})$$

- c** Calculate the mass % copper(II) ions in the copper salt.

$$\text{Answer: \% mass} = \frac{\text{mass}_{\text{copper ions}}}{\text{mass}_{\text{copper salt}}} \times \frac{100}{1}$$

First, calculate the mass of the copper ions. Mass of copper ions is calculated using $m = nM$; (mol \times molar mass).

$$n_{\text{Cu}^{2+}} = 1.488 \times 10^{-3} \text{ mol}$$

$$\text{Molar mass: } M \text{ of } \text{Cu}^{2+} = 63.55 \text{ g mol}^{-1}$$

$$m_{\text{Cu}^{2+}} = (1.488 \times 10^{-3}) \times (63.55) = 0.095 \text{ g}$$

$$\begin{aligned} \text{\% mass of copper (II) ions} &= \frac{0.095 \text{ g}}{\text{mass}_{\text{copper salt}}} \times \frac{100}{1} \\ &= \frac{0.095}{0.245} \times \frac{100}{1} \\ &= 39\% \end{aligned}$$

(2 marks)

(= 6 marks total)

- 6** This table shows the melting points for the elements in period 3.

Element	Na	Mg	Al	Si	P	S	Cl	Ar
Melting point (K)	371	923	933	1680	317	392	172	84

In terms of structure and bonding explain why:

- a** silicon has a high melting point

Answer: Silicon has a high melting point due to its giant covalent or network covalent 3D bonding structure. The strong bonds in a tetrahedral arrangement require high energy to be overcome, hence the high melting point.

(2 marks)

- b** the melting point of sulfur is higher than phosphorous.

Answer: Sulfur exists as a ring S_8 structure and chlorine as a diatomic molecule, Cl_2 . The greater electron density in the sulfur molecule gives it more instantaneous dipoles over the molecule to attract them a little more than the smaller two atom chlorine molecule.

(2 marks)

(= 4 marks total)

7 a Define the term 'electronegativity'.

Answer: Electronegativity is the tendency of an atom to attract electrons. It is dependent on the nuclear charge of the atom and the availability of electron accommodation. (1 mark)

b State and explain the electronegativity across period 3.

Answer: There is increasing electronegativity across a period (and up a row) so chlorine is the most electronegative element and sodium the least.

Argon has no electronegativity because it has a full outer shell.

Chlorine has the highest electronegativity as a result of it needing an extra electron to complete its outer shell. It will attract an electron to do this, becoming an anion.

In contrast, sodium has a lone electron in its outer shell, which will readily delocalise leaving it as a cation, leaving it with a full outer shell. (2 marks)

(= 3 marks total)

8 Calculate the pH of the following solutions.

a 0.2 mol L⁻¹ HCl

Answer: pH = -log[H⁺]

$$= -\log[0.2]$$

$$= 0.7$$

(1 mark)

b 0.05 mol L⁻¹ H₂SO₄

Answer: pH = -log[H⁺], but H₂SO₄ releases 2 mol of H⁺ ions.

$$= -\log[2 \times 0.05]$$

$$= -\log[0.1]$$

$$= 1.0$$

(1 mark)

c 0.05 mol L⁻¹ NaOH

Answer: pH + pOH = 14

$$\text{pH} = 14 - \text{pOH}$$

$$\text{pOH} = -\log[\text{OH}^-]$$

$$\text{pOH} = -\log[0.05]$$

$$\text{pH} = 14 - 1.3$$

$$\text{pH} = 12.7$$

(1 mark)

d 20 g L⁻¹ KOH

Answer: Convert concentration into mol L⁻¹, then calculate pOH to calculate pH.

$$n = \frac{m}{M}, \text{ so } \text{mol L}^{-1} = \frac{\text{g L}^{-1}}{\text{molar mass of KOH}}$$

$$M_{(\text{KOH})} = (39.10 + 16.00 + 1.008) = 56.108 \text{ g mol}^{-1}$$

$$[\text{KOH}] = \frac{20}{56.108} = 0.356 \text{ mol L}^{-1}$$

$$\text{pOH} = -\log 0.356$$

$$\text{pH} = 14 - 0.45$$

$$\text{pH} = 13.55$$

(1 mark)

- e H_2O at 373K given that at 373K, $K_w = 5.13 \times 10^{-13}$.

$$\text{Answer: } K_w = [\text{H}_3\text{O}^+]^2$$

$$[\text{H}^+] = \sqrt{5.13 \times 10^{-13}} = 7.16 \times 10^{-7}$$

$$\text{pH} = -\log(7.16 \times 10^{-7})$$

$$= 6.14$$

(1 mark)

- f Explain why the water is still considered neutral at the pH in the last question (part e).

Answer: Water is still considered neutral because the concentration of hydrogen ions and hydroxide ions are the same as each other.

$$[\text{H}_3\text{O}^+] = [\text{OH}^-], \text{ which means overall it is neutral.}$$

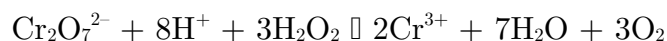
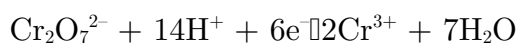
(1 mark)

(= 6 marks total)

- 9 Potassium dichromate ($\text{K}_2\text{Cr}_2\text{O}_7^{2-}$) is used to analyse hydrogen peroxide solutions.

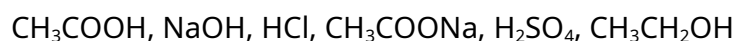
Use half-equations to construct the redox equation for the reaction that occurs when potassium dichromate solution is added to a solution containing hydrogen peroxide in acid.

Answer:



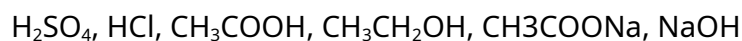
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- 10 List the following 0.1 M solutions in order of increasing pH.

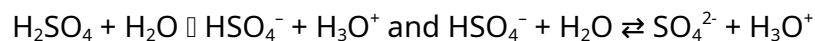


Explain your answers and give equations for each solution as it dissolves in water.

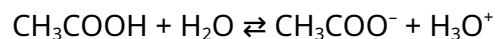
Answer: In order from lowest to highest pH:



H_2SO_4 is diprotic and releases more hydrogen ions than HCl

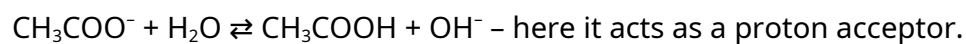
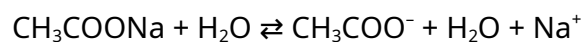


CH_3COOH is a weak acid and weakly dissociates; i.e. most remains in the molecular form of CH_3COOH .



$\text{CH}_3\text{CH}_2\text{OH}$ mixes with water but does not react, so water stays at pH of 7, because water self-ionises to produce a neutral solution of pH 7.

CH_3COONa is a weak base.



(= 4 marks total)