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# HL Paper 1

Which type of bond is formed when a Lewis acid reacts with a Lewis base?

- A. Covalent
- B. Dipole-dipole
- C. Double
- D. Hydrogen

## Markscheme

A

## Examiners report

[N/A]

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Which compounds can be mixed together as solutions of equal volume and concentration to form a buffer solution?

- A. Nitric acid and potassium hydroxide
- B. Nitric acid and potassium nitrate
- C. Propanoic acid and potassium hydroxide
- D. Propanoic acid and potassium propanoate

## Markscheme

D

## Examiners report

One G2 stated that the naming of carboxylic acids was not covered. However, according to AS 10.1.10, candidates should know how to apply IUPAC rules to name carboxylic acids up to six carbon atoms. Hence, it would be expected that candidates would know the structure of propanoic acid to subsequently answer this question on buffer solutions. The question was however the second most difficult question on the paper, with only 43.79% of candidates getting the correct answer.

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Which salt solution has the highest pH?

- A.  $\text{NH}_4\text{Cl}$
- B.  $\text{Ca}(\text{NO}_3)_2$
- C.  $\text{Na}_2\text{CO}_3$
- D.  $\text{K}_2\text{SO}_4$

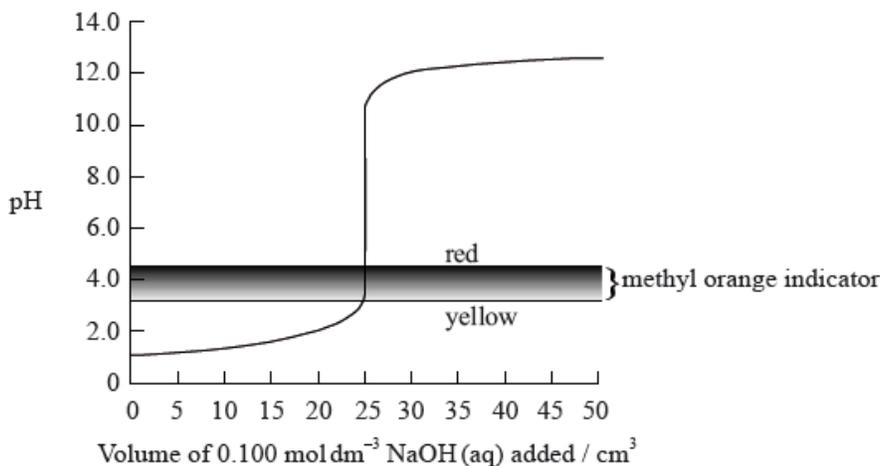
## Markscheme

C

## Examiners report

[N/A]

The graph below shows the titration curve of  $25 \text{ cm}^3$  of  $0.100 \text{ mol dm}^{-3}$  of hydrochloric acid with sodium hydroxide, of  $0.100 \text{ mol dm}^{-3}$  concentration. The indicator methyl orange was used to determine the equivalence point. Methyl orange has a pH range of 3.2– 4.4.



If the hydrochloric acid was replaced by ethanoic acid of the same volume and concentration, which property of the titration would remain the same?

- A. The initial pH
- B. The pH at the equivalence point
- C. The volume of strong base, NaOH, needed to reach the equivalence point
- D. The colour of the titration mixture just before the equivalence point is reached

## Markscheme

C

## Examiners report

There were three G2 comments on this question. Some commented on the length of the question itself. The question certainly was challenging though

53.88% of candidates did manage to get the correct answer C.

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For which equilibrium can an expression for a base dissociation constant,  $K_b$ , for the forward reaction be written?

- A.  $\text{NH}_3 + \text{H}_3\text{O}^+ \rightleftharpoons \text{NH}_4^+ + \text{H}_2\text{O}$
- B.  $\text{F}^- + \text{H}_2\text{O} \rightleftharpoons \text{HF} + \text{OH}^-$
- C.  $\text{NH}_4^+ + \text{OH}^- \rightleftharpoons \text{NH}_3 + \text{H}_2\text{O}$
- D.  $\text{HF} + \text{OH}^- \rightleftharpoons \text{H}_2\text{O} + \text{F}^-$

## Markscheme

B

## Examiners report

[N/A]

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Which statements are correct?

- I. Lewis bases can act as nucleophiles.
  - II. Electrophiles are Lewis acids.
  - III. Lewis acids are electron pair acceptors.
- A. I and II only
  - B. I and III only
  - C. II and III only
  - D. I, II and III

## Markscheme

D

## Examiners report

[N/A]

---

Which combination of acid and base is most likely to have a pH of 8.5 at the equivalence point in a titration?

- A. Hydrochloric acid and sodium hydroxide
- B. Hydrochloric acid and ammonia
- C. Nitric acid and ammonia

- D. Methanoic acid and sodium hydroxide

## Markscheme

D

## Examiners report

[N/A]

---

Which definition of a base is correct?

- A. A Lewis base accepts a proton.
- B. A Brønsted-Lowry base accepts an electron pair.
- C. A Brønsted-Lowry base donates an electron pair.
- D. A Lewis base donates an electron pair.

## Markscheme

D

## Examiners report

[N/A]

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The  $K_b$  value for a base is  $5.0 \times 10^{-2} \text{ mol dm}^{-3}$  at 298 K. What is the  $K_a$  value for its conjugate acid at this temperature?

- A.  $5.0 \times 10^{-2}$
- B.  $2.0 \times 10^{-6}$
- C.  $2.0 \times 10^{-12}$
- D.  $2.0 \times 10^{-13}$

## Markscheme

D

## Examiners report

[N/A]

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The colours of three indicators are shown in the table below.

Indicator	Colour at low pH	Colour at high pH	pH range at which colour change takes place
methyl orange	red	yellow	3.2–4.4
bromothymol blue	yellow	blue	6.0–7.6
phenolphthalein	colourless	pink	8.2–10.0

Equal volumes of these three indicators were mixed and the mixture was added to a solution of  $\text{pH} = 5.0$ . What colour would be seen?

- A. Yellow
- B. Orange
- C. Green
- D. Blue

## Markscheme

A

## Examiners report

[N/A]

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What is the expression for the ionic product constant of water,  $K_w$ ?

- A.  $K_w = K_a \times K_b$
- B.  $K_w = K_a + K_b$
- C.  $K_w = \frac{K_a}{K_b}$
- D.  $K_w = K_a - K_b$

## Markscheme

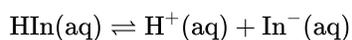
A

## Examiners report

[N/A]

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The indicator, HIn is used in a titration between an acid and base. Which statement about the dissociation of the indicator, HIn is correct?



colour A

colour B

- A. In a strongly alkaline solution, colour B would be observed.
- B. In a strongly acidic solution, colour B would be observed.
- C.  $[\text{In}^-]$  is greater than  $[\text{HIn}]$  at the equivalence point.
- D. In a weakly acidic solution colour B would be observed.

## Markscheme

A

## Examiners report

[N/A]

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The  $K_a$  values of four weak acids W, X, Y and Z are listed below.

W  $K_a = 1.35 \times 10^{-3}$

X  $K_a = 4.47 \times 10^{-2}$

Y  $K_a = 9.33 \times 10^{-6}$

Z  $K_a = 1.47 \times 10^{-5}$

## Markscheme

D

## Examiners report

[N/A]

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The acid–base indicator phenol red, HIn, changes colour from yellow to red over a pH range of 6.6–8.2. Which statement is correct?

- A. In a strongly acidic solution  $[\text{HIn}] < [\text{In}^-]$ .
- B. The  $\text{p}K_a$  of phenol red is between 6.6 and 8.2.
- C. The  $\text{In}^-$  ions are yellow.
- D. Phenol red would be a suitable indicator for the titration of a strong acid and a weak base.

## Markscheme

B

# Examiners report

[N/A]

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Methylamine acts as a weak base when it reacts with water. For a diluted aqueous solution, what is the  $K_b$  expression for this reaction?

- A.  $K_b = \frac{[\text{CH}_3\text{NH}_3^+][\text{OH}^-]}{[\text{CH}_3\text{NH}_2]}$
- B.  $K_b = \frac{[\text{CH}_3\text{NH}_2][\text{H}_2\text{O}]}{[\text{CH}_3\text{NH}_3^+][\text{OH}^-]}$
- C.  $K_b = \frac{[\text{CH}_3\text{NH}_3^+][\text{OH}^-]}{[\text{CH}_3\text{NH}_2][\text{H}_2\text{O}]}$
- D.  $K_b = \frac{[\text{CH}_3\text{NH}_2]}{[\text{CH}_3\text{NH}_3^+][\text{OH}^-]}$

## Markscheme

A

# Examiners report

Quite a few candidates included water in the expression, giving answer C.

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Four aqueous solutions are listed below.

- W.  $0.100 \text{ mol dm}^{-3} \text{ HNO}_3(\text{aq})$
- X.  $0.001 \text{ mol dm}^{-3} \text{ HNO}_3(\text{aq})$
- Y.  $0.100 \text{ mol dm}^{-3} \text{ KOH}(\text{aq})$
- Z.  $0.001 \text{ mol dm}^{-3} \text{ KOH}(\text{aq})$

What is the correct order of **increasing** pH of these solutions?

- A.  $W < X < Y < Z$
- B.  $W < X < Z < Y$
- C.  $X < W < Y < Z$
- D.  $X < W < Z < Y$

## Markscheme

B

# Examiners report

[N/A]

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Which of the following is an example of a Lewis acid–base reaction, but not a Brønsted–Lowry acid–base reaction?

- A.  $2\text{CrO}_4^{2-}(\text{aq}) + 2\text{H}^+(\text{aq}) \rightarrow \text{Cr}_2\text{O}_7^{2-}(\text{aq}) + \text{H}_2\text{O}(\text{l})$
- B.  $\text{Co}(\text{H}_2\text{O})_6^{2+}(\text{aq}) + 4\text{HCl}(\text{aq}) \rightarrow \text{CoCl}_4^{2-}(\text{aq}) + 4\text{H}^+(\text{aq}) + 6\text{H}_2\text{O}(\text{l})$
- C.  $\text{NH}_3(\text{aq}) + \text{H}^+(\text{aq}) \rightarrow \text{NH}_4^+(\text{aq})$
- D.  $\text{CH}_3\text{COO}^-(\text{aq}) + \text{H}_2\text{O}(\text{l}) \rightarrow \text{CH}_3\text{COOH}(\text{aq}) + \text{OH}^-(\text{aq})$

## Markscheme

B

## Examiners report

[N/A]

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Which equation represents a reaction for which a base dissociation constant expression,  $K_b$ , can be written?

- A.  $\text{CH}_3\text{COOH}(\text{aq}) + \text{NH}_3(\text{aq}) \rightleftharpoons \text{CH}_3\text{COO}^-(\text{aq}) + \text{NH}_4^+(\text{aq})$
- B.  $\text{HF}(\text{aq}) \rightleftharpoons \text{H}^+(\text{aq}) + \text{F}^-(\text{aq})$
- C.  $\text{HCN}(\text{aq}) + \text{OH}^-(\text{aq}) \rightleftharpoons \text{CN}^-(\text{aq}) + \text{H}_2\text{O}(\text{l})$
- D.  $\text{NH}_3(\text{aq}) + \text{H}_2\text{O}(\text{l}) \rightleftharpoons \text{NH}_4^+(\text{aq}) + \text{OH}^-(\text{aq})$

## Markscheme

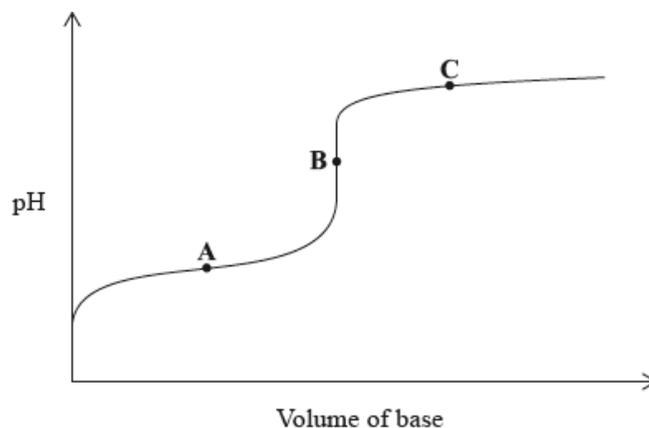
D

## Examiners report

[N/A]

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A weak acid is titrated with a strong base. Which statement is true for the titration curve?



- A. **A** is the equivalence point.
- B. The pH at **A** equals the  $pK_a$  of the acid.
- C. The pH at **B** equals 7.
- D. **C** is in the buffer region.

## Markscheme

B

## Examiners report

[N/A]

Which mixture will form a buffer in aqueous solution?

- A. 0.10 mol  $\text{NH}_3$  + 0.20 mol HCl
- B. 0.10 mol  $\text{NH}_3$  + 0.20 mol NaOH
- C. 0.10 mol NaOH + 0.20 mol KCl
- D. 0.20 mol  $\text{NH}_3$  + 0.10 mol HCl

## Markscheme

D

## Examiners report

[N/A]

Ammonia acts as a weak base when it reacts with water. What is the  $K_b$  expression for this reaction?

- A.  $\frac{[\text{NH}_4^+][\text{OH}^-]}{[\text{NH}_3][\text{H}_2\text{O}]}$

B.  $\frac{[\text{NH}_3][\text{H}_2\text{O}]}{[\text{NH}_4^+][\text{OH}^-]}$

C.  $\frac{[\text{NH}_3]}{[\text{NH}_4^+][\text{OH}^-]}$

D.  $\frac{[\text{NH}_4^+][\text{OH}^-]}{[\text{NH}_3]}$

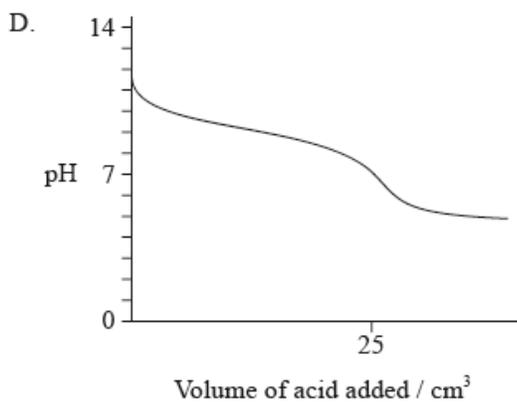
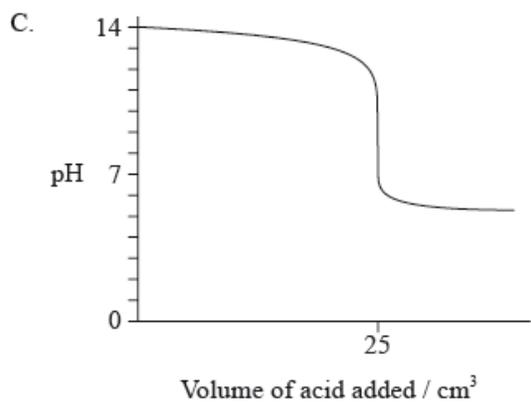
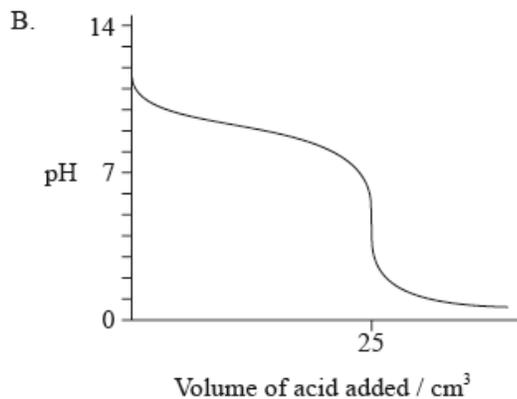
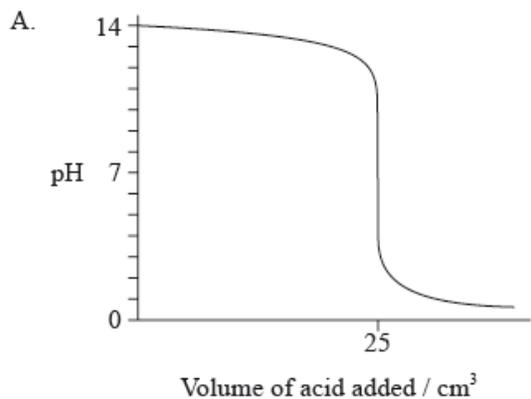
## Markscheme

D

## Examiners report

[N/A]

Which titration curve is produced by the titration of 25 cm<sup>3</sup> of 1.00 mol dm<sup>-3</sup> NaOH with 1.00 mol dm<sup>-3</sup> CH<sub>3</sub>COOH?



## Markscheme

C

## Examiners report

[N/A]

---

Which reaction represents an acid–base reaction according to the Lewis theory but not according to the Brønsted–Lowry theory?

- A.  $\text{CO}_3^{2-}(\text{aq}) + \text{H}_3\text{O}^+(\text{aq}) \rightleftharpoons \text{H}_2\text{O}(\text{l}) + \text{HCO}_3^-(\text{aq})$
- B.  $\text{CH}_3\text{COOH}(\text{aq}) + \text{NH}_3(\text{aq}) \rightleftharpoons \text{NH}_4^+(\text{aq}) + \text{CH}_3\text{COO}^-(\text{aq})$
- C.  $\text{NH}_3(\text{aq}) + \text{HF}(\text{aq}) \rightleftharpoons \text{NH}_4^+(\text{aq}) + \text{F}^-(\text{aq})$
- D.  $\text{CuSO}_4(\text{s}) + 5\text{H}_2\text{O}(\text{l}) \rightleftharpoons \text{CuSO}_4 \cdot 5\text{H}_2\text{O}(\text{s})$

## Markscheme

D

## Examiners report

[N/A]

---

Which is an example of a Lewis base?

- A. an electrophile
- B.  $\text{BF}_3$
- C.  $\text{CH}_4$
- D. a nucleophile

## Markscheme

D

## Examiners report

[N/A]

---

Which mixtures could act as buffers?

- I.  $\text{NaOH}(\text{aq})$  and  $\text{HCl}(\text{aq})$
  - II.  $\text{NaOH}(\text{aq})$  and  $\text{CH}_3\text{COOH}(\text{aq})$
  - III.  $\text{HCl}(\text{aq})$  and  $\text{CH}_3\text{COONa}(\text{aq})$
- A. I and II only
  - B. I and III only
  - C. II and III only
  - D. I, II and III

# Markscheme

C

## Examiners report

One respondent stated that this question was fair but tricky. However, this question is based on the syllabus, as stated in AS 18.2.2. In the teachers notes on buffers, selected examples are given. It should be emphasized that buffer solutions should not be confined solely to these examples but these examples should be included in the teaching programme.

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At the same concentration, which acid would have the lowest pH?

- A.  $\text{HNO}_2$        $K_a = 5.6 \times 10^{-4} \text{ mol dm}^{-3}$
- B.  $\text{HF}$        $K_a = 6.8 \times 10^{-4} \text{ mol dm}^{-3}$
- C.  $\text{C}_6\text{H}_5\text{COOH}$        $K_a = 6.3 \times 10^{-5} \text{ mol dm}^{-3}$
- D.  $\text{HCN}$        $K_a = 4.9 \times 10^{-10} \text{ mol dm}^{-3}$

# Markscheme

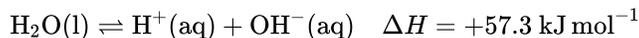
B

## Examiners report

[N/A]

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Consider the equation for the dissociation of water:



Which statement is correct?

- A. The pH of pure water is always 7.
- B. At temperatures above 298 K the pH of pure water is below 7.
- C. At temperatures above 298 K the pH of pure water is above 7.
- D.  $K_w$  decreases with increasing temperature.

# Markscheme

B

## Examiners report

[N/A]

---

Which pair of compounds could be used to make a buffer solution (assuming appropriate molar ratios)?

- A. KCl and HCl
- B. NaCl and HCl
- C.  $\text{KHSO}_4$  and  $\text{H}_2\text{SO}_4$
- D.  $\text{CH}_3\text{COONa}$  and  $\text{CH}_3\text{COOH}$

## Markscheme

D

## Examiners report

[N/A]

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During a titration,  $0.1 \text{ mol dm}^{-3}$  sodium hydroxide is added to  $0.1 \text{ mol dm}^{-3}$  ethanoic acid. Which indicator would be the **best** to use as an end point indicator in this titration?

	Indicator	pH range of indicator
A.	methyl orange	3.2–4.4
B.	bromophenol blue	3.0–4.6
C.	bromothymol blue	6.0–7.6
D.	phenolphthalein	8.2–10.0

## Markscheme

D

## Examiners report

[N/A]

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Bromophenol blue changes from yellow to blue over the pH range of 3.0 to 4.6. Which statement is correct?

- A. Molecules of bromophenol blue,  $\text{HIn}$ , are blue.
- B. At  $\text{pH} < 3.0$ , a solution of bromophenol blue contains more ions,  $\text{In}^-$ , than molecules,  $\text{HIn}$ .

- C. The  $pK_a$  of bromophenol blue is between 3.0 and 4.6.
- D. Bromophenol blue is a suitable indicator to titrate ethanoic acid with potassium hydroxide solution.

## Markscheme

C

## Examiners report

[N/A]

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$100\text{ cm}^3$  of a NaOH solution of pH 12 is mixed with  $900\text{ cm}^3$  of water. What is the pH of the resulting solution?

- A. 1
- B. 3
- C. 11
- D. 13

## Markscheme

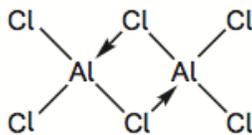
C

## Examiners report

[N/A]

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The diagram represents the bonding in aluminium chloride.



Which statement is correct?

- A. The aluminium atoms behave as Lewis acids.
- B. The aluminium atoms behave as Lewis bases.
- C. One aluminium atom is a Lewis base and the other a Lewis acid.
- D. One chlorine atom is a Lewis base and the other a Lewis acid.

## Markscheme

A

## Examiners report

[N/A]

---

Equal volumes and concentrations of hydrochloric acid and ethanoic acid are titrated with sodium hydroxide solutions of the same concentration.

Which statement is correct?

- A. The initial pH values of both acids are equal.
- B. At the equivalence points, the solutions of both titrations have pH values of 7.
- C. The same volume of sodium hydroxide is needed to reach the equivalence point.
- D. The pH values of both acids increase equally until the equivalence points are reached.

## Markscheme

C

## Examiners report

[N/A]

---

Which statements are correct about the complex  $[\text{Cu}(\text{NH}_3)_2\text{Cl}_2]$ ?

- I. Oxidation state of copper is +2.
  - II. Ammonia is a ligand.
  - III. Chloride ions act as Lewis acids.
- A. I and II only
  - B. I and III only
  - C. II and III only
  - D. I, II and III

## Markscheme

A

## Examiners report

Although several teachers had concerns about this one, overall it was a fair question with half the students answering it correctly. Surprisingly a quarter of the students incorrectly identified chloride ions acting as Lewis acids.

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In which reaction does  $\text{H}_2\text{O}$  act as a Lewis base but not as a Brønsted–Lowry base.

- A.  $\text{H}_2\text{O} + \text{NH}_4^+ \rightarrow \text{H}_3\text{O}^+ + \text{NH}_3$
- B.  $\text{H}_2\text{O} + \text{CaO} \rightarrow \text{Ca}^{2+} + 2\text{OH}^-$
- C.  $\text{H}_2\text{O} + [\text{Fe}(\text{H}_2\text{O})_6]^{3+} \rightarrow \text{Fe}[(\text{OH})(\text{H}_2\text{O})_5]^{2+} + \text{H}_3\text{O}^+$
- D.  $6\text{H}_2\text{O} + [\text{Ni}(\text{NH}_3)_6]^{2+} \rightarrow 6\text{NH}_3 + [\text{Ni}(\text{H}_2\text{O})_6]^{2+}$

## Markscheme

D

## Examiners report

[N/A]

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The strengths of four acids are:

glycine  $\text{p}K_{\text{a}} = 9.87$

chloroethanoic acid  $K_{\text{a}} = 1.38 \times 10^{-3}$

phenol  $K_{\text{a}} = 1.00 \times 10^{-10}$

butanoic acid  $\text{p}K_{\text{a}} = 4.82$

What is the order of **increasing** acid strength?

- A. chloroethanoic acid < butanoic acid < phenol < glycine
- B. glycine < phenol < chloroethanoic acid < butanoic acid
- C. phenol < chloroethanoic acid < butanoic acid < glycine
- D. phenol < glycine < butanoic acid < chloroethanoic acid

## Markscheme

D

## Examiners report

Candidates should be able to make an approximation of the inter-conversion of  $K_{\text{a}}$  and  $\text{p}K_{\text{a}}$  values. 69% of the candidates found no difficulty with this question.

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Based on information in the table below, which acid is the strongest?

	Acid	$pK_a$	$K_a$
A.	HA	2.0	–
B.	HB	–	$1 \times 10^{-3}$
C.	HC	4.0	–
D.	HD	–	$1 \times 10^{-5}$

## Markscheme

A

## Examiners report

[N/A]

---

Methyl orange is an indicator which changes its colour from red to yellow in a pH range of 3.2 – 4.4.

For which titration would methyl orange be a suitable indicator?

- A. Iodine and sodium thiosulfate solution
- B. Hydrochloric acid and ammonia solution
- C. Ethanoic acid and sodium hydroxide solution
- D. Ethanoic acid and ammonia solution

## Markscheme

B

## Examiners report

[N/A]

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The  $pK_b$  of  $HS^-$  is 7.08. What is its conjugate acid and what is the  $K_a$  value of the acid?

	Conjugate acid	$K_a$
A.	H <sub>2</sub> S	$10^{-6.92}$
B.	H <sub>2</sub> S	6.92
C.	S <sup>2-</sup>	$10^{-6.92}$
D.	S <sup>2-</sup>	6.92

## Markscheme

A

## Examiners report

[N/A]

Cobalt forms the complex  $[\text{Co}(\text{NH}_3)_5\text{Cl}]^{2+}$ . Which statements are correct for this complex?

- I. The cobalt ion acts as a Lewis acid.
  - II. The cobalt ion has an oxidation number of +II.
  - III. There are 90° bond angles between the cobalt ion and the ligands.
- A. I and II only
  - B. I and III only
  - C. II and III only
  - D. I, II and III

## Markscheme

B

## Examiners report

According to IUPAC, oxidation numbers are quoted in Roman numerals, oxidation states in Arabic. The nomenclature is clarified in the new syllabus, taught from September 2014.

Which of the following will form a buffer solution if combined in appropriate molar ratios?

- A. HCl and NaCl
- B. NaOH and HCOONa
- C. NH<sub>4</sub>Cl and HCl

D. HCl and NH<sub>3</sub>

## Markscheme

D

## Examiners report

[N/A]

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Which mixtures are buffer solutions?

- I. KHSO<sub>4</sub>(aq) and H<sub>2</sub>SO<sub>4</sub>(aq)
  - II. CH<sub>3</sub>COONa(aq) and CH<sub>3</sub>COOH(aq)
  - III. HCOOK(aq) and HCOOH(aq)
- A. I and II only
  - B. I and III only
  - C. II and III only
  - D. I, II and III

## Markscheme

C

## Examiners report

[N/A]

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For which titration can the end point **not** be determined accurately by using an acid-base indicator?

- A. NH<sub>3</sub>(aq) + CH<sub>3</sub>COOH(aq)
- B. NaOH(aq) + HNO<sub>3</sub>(aq)
- C. NH<sub>3</sub>(aq) + HNO<sub>3</sub>(aq)
- D. NaOH(aq) + CH<sub>3</sub>COOH(aq)

## Markscheme

A

## Examiners report

The table below shows data for the  $K_a$  and  $pK_b$  values for some acids and bases at 298 K.

Acid	$K_a$	Base	$pK_b$
HClO	$2.9 \times 10^{-8}$	$\text{NH}_3$	4.75
$\text{C}_6\text{H}_5\text{CH}_2\text{COOH}$	$4.9 \times 10^{-5}$	$\text{C}_6\text{H}_5\text{NH}_2$	9.13

Which two formulas represent the weakest acid and the weakest base in the table?

- A. HClO and  $\text{C}_6\text{H}_5\text{NH}_2$
- B.  $\text{C}_6\text{H}_5\text{CH}_2\text{COOH}$  and  $\text{NH}_3$
- C.  $\text{C}_6\text{H}_5\text{CH}_2\text{COOH}$  and  $\text{C}_6\text{H}_5\text{NH}_2$
- D. HClO and  $\text{NH}_3$

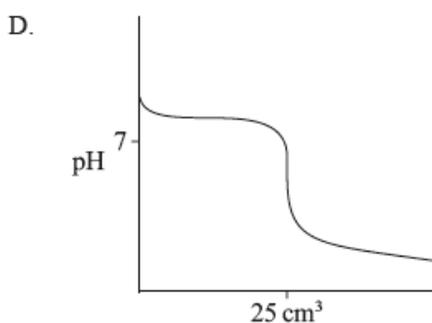
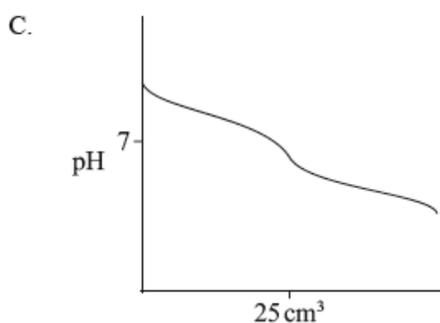
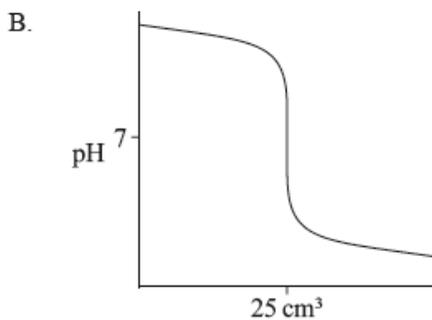
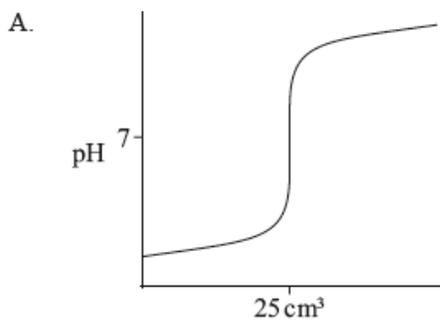
## Markscheme

A

## Examiners report

It was thought “good to mix the data types,  $pK_a$  and  $K_a$ ”. This was the fifth hardest question (60.81% correct) with the wrong answers almost equally chosen.

Which graph would be obtained by adding  $0.10 \text{ mol dm}^{-3} \text{HCl(aq)}$  to  $25 \text{ cm}^3$  of  $0.10 \text{ mol dm}^{-3} \text{NaOH(aq)}$ ?



# Markscheme

B

## Examiners report

[N/A]

---

The  $pK_b$  value of ammonia is 4.75 at 298 K. What is the  $pK_a$  value of the ammonium ion?

- A.  $\frac{10^{-14}}{4.75}$
- B.  $\frac{14.00}{4.75}$
- C.  $14.00 - 4.75$
- D.  $\frac{10^{-14}}{10^{-4.75}}$

# Markscheme

C

## Examiners report

We acknowledge the error in asking for the  $pK_a$  of ammonia; it should, of course, have been the  $pK_a$  of the ammonium ion. Nevertheless, over 79% of candidates chose the correct key (C) for answer.

---

Which compound will produce an aqueous solution which has a pH greater than 7?

- A.  $\text{CuSO}_4$
- B.  $\text{FeCl}_3$
- C.  $\text{Na}_2\text{CO}_3$
- D.  $\text{NH}_4\text{NO}_3$

# Markscheme

C

## Examiners report

[N/A]

---

Which mixture is a buffer solution?

- A. 25 cm<sup>3</sup> of 0.10 mol dm<sup>-3</sup> NH<sub>3</sub> (aq) and 50 cm<sup>3</sup> of 0.10 mol dm<sup>-3</sup> HCl (aq)
- B. 50 cm<sup>3</sup> of 0.10 mol dm<sup>-3</sup> NH<sub>3</sub> (aq) and 25 cm<sup>3</sup> of 0.10 mol dm<sup>-3</sup> HCl (aq)
- C. 25 cm<sup>3</sup> of 0.10 mol dm<sup>-3</sup> NaOH (aq) and 25 cm<sup>3</sup> of 0.10 mol dm<sup>-3</sup> HCl (aq)
- D. 50 cm<sup>3</sup> of 0.10 mol dm<sup>-3</sup> NaOH (aq) and 25 cm<sup>3</sup> of 0.10 mol dm<sup>-3</sup> HCl (aq)

## Markscheme

B

## Examiners report

[N/A]

---

The values of  $K_w$ , the ionic product constant of water, are:

$K_w$	T / °C
$6.4 \times 10^{-15}$	18
$1.0 \times 10^{-14}$	25

Which statements are correct?

- I. The [OH<sup>-</sup>] in water is less than the [H<sup>+</sup>] at 18 °C.
  - II. The ionization of water is an endothermic process.
  - III. The pH of water is lower at 25 °C than at 18 °C.
- A. I and II only
  - B. I and III only
  - C. II and III only
  - D. I, II and III

## Markscheme

C

## Examiners report

[N/A]

---

What is the approximate pH of a 0.01 mol dm<sup>-3</sup> ammonia solution?

- A. 2
- B. More than 2 but less than 7

- C. More than 7 but less than 12  
D. 12

## Markscheme

C

## Examiners report

[N/A]

---

What is the order of increasing acidity?

Acid	$pK_a$
HClO	7.4
HIO <sub>3</sub>	0.8

Acid	$K_a$
HF	$5.6 \times 10^{-4}$
CH <sub>3</sub> CH <sub>2</sub> COOH	$1.3 \times 10^{-5}$

- A. HClO < CH<sub>3</sub>CH<sub>2</sub>COOH < HF < HIO<sub>3</sub>  
B. HClO < HF < CH<sub>3</sub>CH<sub>2</sub>COOH < HIO<sub>3</sub>  
C. HIO<sub>3</sub> < HF < CH<sub>3</sub>CH<sub>2</sub>COOH < HClO  
D. HIO<sub>3</sub> < CH<sub>3</sub>CH<sub>2</sub>COOH < HF < HClO

## Markscheme

A

## Examiners report

[N/A]

---

What is the order of increasing acidity of the following acids?

Acid	$K_a$
chloroethanoic	$1.3 \times 10^{-3}$
ethanoic	$1.7 \times 10^{-5}$

Acid	$pK_a$
hydrogen fluoride	3.3
hydrogen cyanide	9.3

- A. chloroethanoic < ethanoic < hydrogen fluoride < hydrogen cyanide  
B. ethanoic < chloroethanoic < hydrogen fluoride < hydrogen cyanide  
C. chloroethanoic < ethanoic < hydrogen cyanide < hydrogen fluoride  
D. hydrogen cyanide < ethanoic < hydrogen fluoride < chloroethanoic

## Markscheme

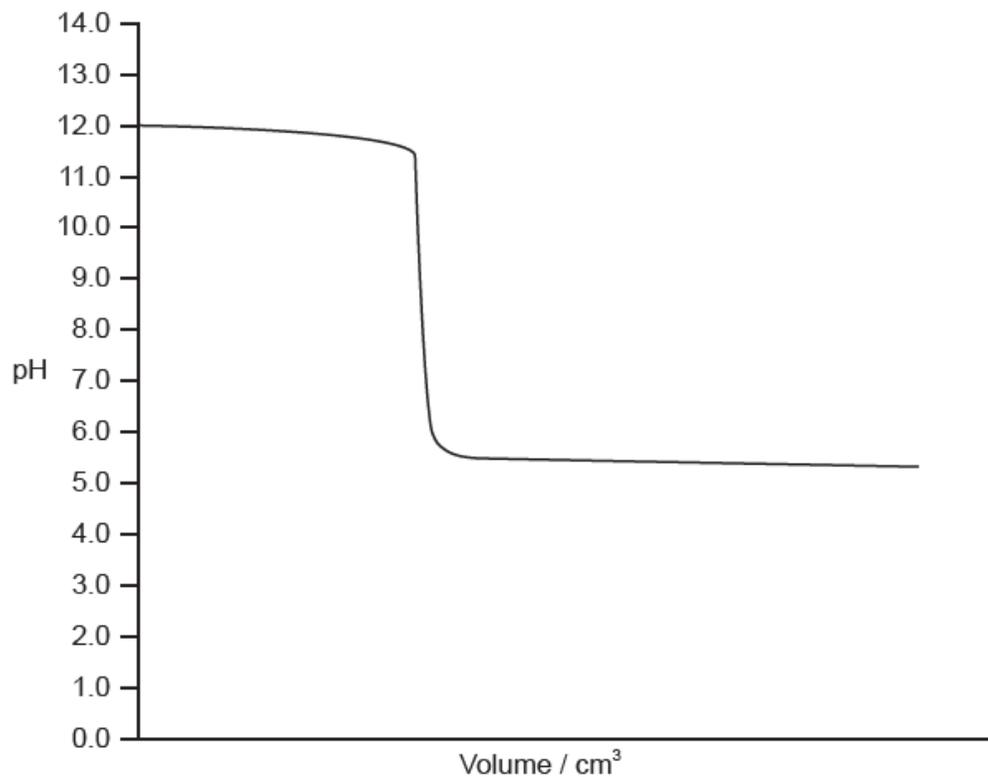
D

## Examiners report

[N/A]

---

Which indicator is appropriate for the acid-base titration shown below?



- A. Thymol blue ( $pK_a = 1.5$ )
- B. Methyl orange ( $pK_a = 3.7$ )
- C. Bromophenol blue ( $pK_a = 4.2$ )
- D. Phenolphthalein ( $pK_a = 9.6$ )

## Markscheme

D

## Examiners report

[N/A]

---

A buffer is produced by mixing 20.0 cm<sup>3</sup> of 0.10 mol dm<sup>-3</sup> ethanoic acid, CH<sub>3</sub>COOH(aq), with 0.10 mol dm<sup>-3</sup> sodium hydroxide, NaOH(aq).

What is the volume of NaOH required and the pH of the buffer?

	Volume of NaOH / cm <sup>3</sup>	pH of buffer
A.	40.0	9.2
B.	40.0	4.8
C.	10.0	9.2
D.	10.0	4.8

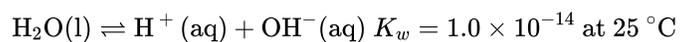
## Markscheme

D

## Examiners report

[N/A]

The forward reaction of this equilibrium is endothermic.



What is correct about water at 50 °C?

- A.  $[\text{H}^+] > [\text{OH}^-]$
- B.  $[\text{H}^+] < [\text{OH}^-]$
- C.  $\text{pH} < 7.0$
- D.  $\text{pH} = 7.0$

## Markscheme

C

## Examiners report

[N/A]

Which indicator would be the most appropriate for titrating aqueous ethylamine,  $\text{CH}_3\text{CH}_2\text{NH}_2$ , with nitric acid,  $\text{HNO}_3$ ?

- A. Bromophenol blue ( $\text{p}K_a = 4.1$ )
- B. Bromothymol blue ( $\text{p}K_a = 7.3$ )
- C. Phenol red ( $\text{p}K_a = 8.0$ )
- D. Thymolphthalein ( $\text{p}K_a = 10.0$ )

# Markscheme

A

## Examiners report

[N/A]

---

Which mixture of solutions can be used to prepare a buffer solution?

- A.  $50.0 \text{ cm}^3$   $0.100 \text{ mol dm}^{-3}$  HCl and  $100.0 \text{ cm}^3$   $0.100 \text{ mol dm}^{-3}$   $\text{NH}_3$
- B.  $50.0 \text{ cm}^3$   $0.100 \text{ mol dm}^{-3}$  HCl and  $50.0 \text{ cm}^3$   $0.100 \text{ mol dm}^{-3}$   $\text{NH}_3$
- C.  $50.0 \text{ cm}^3$   $0.100 \text{ mol dm}^{-3}$  HCl and  $100.0 \text{ cm}^3$   $0.100 \text{ mol dm}^{-3}$   $\text{NH}_4\text{Cl}$
- D.  $50.0 \text{ cm}^3$   $0.100 \text{ mol dm}^{-3}$  HCl and  $50.0 \text{ cm}^3$   $0.100 \text{ mol dm}^{-3}$   $\text{NH}_4\text{Cl}$

# Markscheme

A

## Examiners report

[N/A]

---

An equal amount of each of the following salts is added separately to the same volume of water.

Which salt will have the greatest effect on the pH of water?

- A.  $\text{Al}(\text{NO}_3)_3$
- B.  $\text{Na}_2\text{SO}_4$
- C. RbCl
- D. KBr

# Markscheme

A

## Examiners report

Students found this question to be somewhat difficult with 41.96% correct answers. The salt in each of the other three choices is neutral (made up of strong acid and a strong base) whereas the effect of the high charge density of the aluminium ion in the complex ion formed,  $[\text{Al}(\text{H}_2\text{O})_6]^{3+}$ , produces an acidic solution.

---

Which compound forms an acidic solution when dissolved in water?

- A.  $\text{FeCl}_3$
- B.  $\text{CH}_3\text{NH}_2$
- C.  $\text{NaNO}_3$
- D.  $\text{Na}_2\text{CO}_3$

## Markscheme

A

## Examiners report

[N/A]

---

Which compounds can be mixed together as aqueous solutions of equal volume and concentration to form an acidic buffer solution?

- A. Sodium hydrogensulfate and sulfuric acid
- B. Sodium propanoate and propanoic acid
- C. Ammonium chloride and ammonia solution
- D. Sodium chloride and hydrochloric acid

## Markscheme

B

## Examiners report

[N/A]

---

Which statements about an acid–base indicator are correct?

- I. It can be a weak acid.
  - II. It is a substance in which the conjugate acid/base pair are different colours.
  - III. It can be a weak base.
- A. I and II only
  - B. I and III only
  - C. II and III only

D. I, II and III

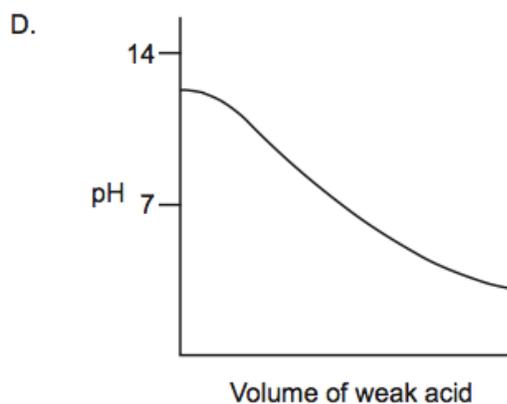
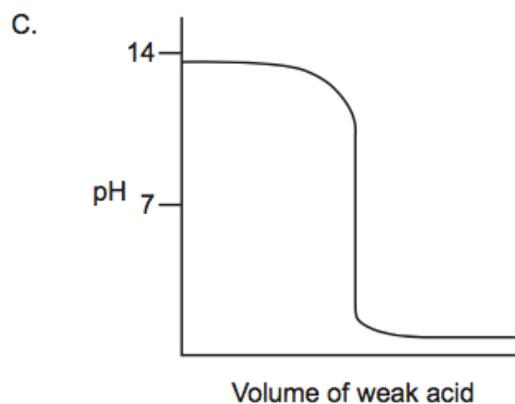
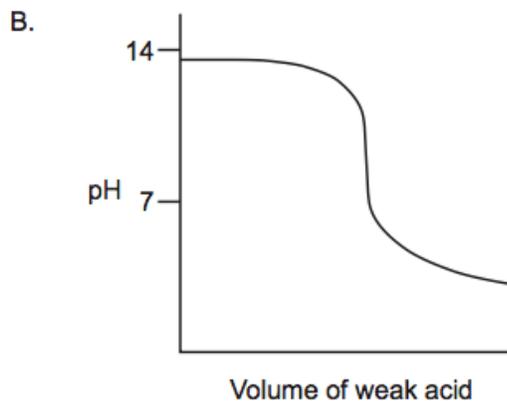
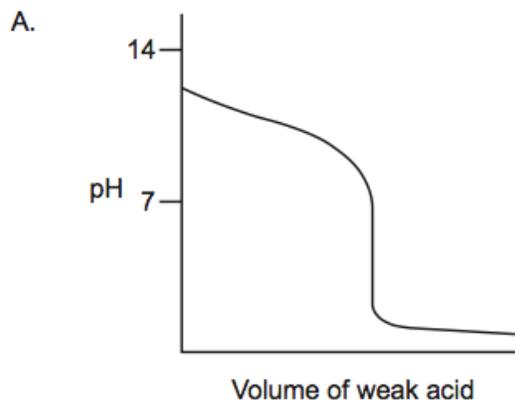
## Markscheme

D

## Examiners report

The point was made by several people that weak base indicators are beyond the scope of the specification. In fairness to the candidates it was decided to accept both answers A and D.

Which titration curve would occur when a weak acid is added to a strong base?



## Markscheme

B

## Examiners report

[N/A]