Topic 18.1 Lewis Acids & Bases

Past Exam Questions (Paper 1, 2)

1. *[1 mark]*

According to the Brønsted-Lowry theory, how does each species act in the equilibrium below?

$$CH_3COOH + H_2SO_4 \rightleftharpoons CH_3COOH_2^+ + HSO_4^-$$

	CH_3COOH	H_2SO_4	$CH_3COOH_2^+$	HSO_4^-
A.	acid	base	base	acid
B.	acid	base	acid	base
C.	base	acid	base	acid
D.	base	acid	acid	base

2. *[1 mark]*

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

A. $CO_3^{2-}(aq) + H_3O^+(aq) \rightleftharpoons H_2O(l) + HCO_3^-(aq)$

B. $CH_3COOH(aq) + NH_3(aq) \rightleftharpoons NH_4^+(aq) + CH_3COO^-(aq)$

C. $NH_3(aq) + HF(aq) \rightleftharpoons NH_4^+(aq) + F^-(aq)$

D. $CuSO_4(s) + 5H_2O(l) \rightleftharpoons CuSO_4 \bullet 5H_2O(s)$

3. *[1 mark]*

What are the conjugate acid–base pairs in the following reaction?

$$HCO_3^-(aq) + H_2O(l) \rightleftharpoons OH^-(aq) + H_2CO_3(aq)$$

	Brønsted–Lowry acid	Brønsted–Lowry base	Conjugate acid	Conjugate base
A.	$HCO_3^-(aq)$	$H_2O(l)$	$H_2CO_3(aq)$	$OH^-(aq)$
B.	$H_2CO_3(aq)$	$OH^-(aq)$	$HCO_3^-(aq)$	$H_2O(l)$
C.	$H_2O(l)$	$HCO_3^-(aq)$	$H_2CO_3(aq)$	$OH^-(aq)$
D.	$H_2O(l)$	$HCO_3^-(aq)$	$OH^-(aq)$	$H_2CO_3(aq)$

4. *[1 mark]*

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

A. $2CrO_4^{2-}(aq) + 2H^+(aq) \rightarrow Cr_2O_7^{2-}(aq) + H_2O(l)$

B. $Co(H_2O)_6^{2+}(aq) + 4HCl(aq) \rightarrow CoCl_4^{2-}(aq) + 4H^+(aq) + 6H_2O(l)$

C. $NH_3(aq) + H^+(aq) \rightarrow NH_4^+(aq)$

D. $CH_3COO^-(aq) + H_2O(l) \rightarrow CH_3COOH(aq) + OH^-(aq)$

5. *[1 mark]*

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.

6. *[1 mark]*

Cobalt forms the complex $[Co(NH_3)_5Cl]^{2+}$. 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

7. *[1 mark]*

In which reaction does H_2O act as a Lewis base but not as a Brønsted–Lowry base.

A. $H_2O + NH_4^+ \rightarrow H_3O^+ + NH_3$

B. $H_2O + CaO \rightarrow Ca^{2+} + 2OH^-$

C. $H_2O + [Fe(H_2O)_6]^{3+} \rightarrow Fe[(OH)(H_2O)_5]^{2+} + H_3O^+$

D. $6H_2O + [Ni(NH_3)_6]^{2+} \rightarrow 6NH_3 + [Ni(H_2O)_6]^{2+}$

8. *[1 mark]*

What is the conjugate base of phenol, C_6H_5OH?

A. $C_6H_4^-$–OH

B. C_6H_5–O^+H_2

C. C_6H_5–O^-

D. $C_6H_6^+$–OH

9. *[1 mark]*

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. $Al(NO_3)_3$

B. Na_2SO_4

C. RbCl

D. KBr

10. *[1 mark]*

Which statements are correct about the complex $[Cu(NH_3)_2Cl_2]$?

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

11. *[1 mark]*

Which compound forms an acidic solution when dissolved in water?

A. $FeCl_3$

B. CH_3NH_2

C. $NaNO_3$

D. Na_2CO_3

12. *[1 mark]*

Which are definitions of an acid according to the Brønsted-Lowry and Lewis theories?

	Brønsted-Lowry theory	Lewis theory
A.	proton donor	electron pair acceptor
B.	proton acceptor	electron pair acceptor
C.	proton acceptor	electron pair donor
D.	proton donor	electron pair donor

13. *[1 mark]*

Which descriptions are correct for both a Brønsted–Lowry acid and a Lewis acid?

	Brønsted–Lowry acid	Lewis acid
A.	proton donor	electron pair donor
B.	proton donor	electron pair acceptor
C.	proton acceptor	electron pair donor
D.	proton acceptor	electron pair acceptor

14. *[1 mark]*

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

A. HCl

B. CH_3COOH

C. BF_3

D. CF_3COOH

15. *[1 mark]*

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.

16. *[1 mark]*

Which statement explains why ammonia, NH_3, is classified as a Lewis base?

A. It can accept a proton.

B. It can accept a lone pair of electrons.

C. It can donate a lone pair of electrons.

D. It can donate a proton.

17. *[1 mark]*

Which species **cannot** function as a Lewis acid?

A. BF_3

B. $AlCl_3$

C. CCl_4

D. H^+

18. *[1 mark]*

Ammonia, NH_3, is a weak base. It has a pK_b value of 4.75.

Another weak base is nitrogen trifluoride, NF_3. Explain how NF_3 is able to function as a Lewis base.

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19a. *[2 marks]*

Antimony, Sb, forms a fluoride, SbF_5.

The equilibrium that occurs when antimony(V) fluoride is dissolved in liquid hydrogen fluoride can be represented by the equation below.

$$SbF_5(s) + 2HF(l) \rightleftharpoons SbF_6^-(sol) + H_2F^+(sol)$$

Describe the relationship between SbF_5 and SbF_6^- in terms of the Lewis theory of acids.

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19b. *[2 marks]*

Explain the behaviour of HF in terms of the Brønsted–Lowry theory of acids.

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19c. *[1 mark]*

Outline how the following factors account for the fact that HCl is a strong acid and HF is a weak acid.

The strength of the hydrogen–halogen bond.

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19d. *[1 mark]*

The interaction between an undissociated hydrogen halide molecule and a water molecule.

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20a. *[1 mark]*

The element boron has two naturally occurring isotopes, ^{10}B and ^{11}B.

Phosphorus forms two chlorides, PCl_3 and PCl_5.

Define an *acid* according to the Lewis theory.

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20b. *[2 marks]*

State and explain the acid–base character of PCl_3 according to the Lewis theory.

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21. *[2 marks]*

Acid–base chemistry can play a major role in chemical and biological processes.

White vinegar, which contains ethanoic acid, CH_3COOH, can be used as a cleaning agent to dissolve mineral deposits from coffee machines.

Define an *acid* according to the Brønsted–Lowry theory and the Lewis theory.

Brønsted–Lowry theory:

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Lewis theory:

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22a. *[1 mark]*

When nitrogen gas and hydrogen gas are allowed to react in a closed container the following equilibrium is established.

$$N_2(g) + 3H_2(g) \rightleftharpoons 2NH_3(g) \; \Delta H = -92.6\ kJ$$

Define the term *base* according to the Lewis theory.

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22b. *[2 marks]*

Deduce the formulas of conjugate acid-base pairs in the reaction below.

$$CH_3NH_2(aq) + H_2O(l) \rightleftharpoons CH_3NH_3^+(aq) + OH^-(aq)$$

Acid	Conjugate base
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