1. Define the terms *acid* and *base* according to the Brønsted-Lowry theory **and** state **one** example of a weak acid and **one** example of a strong base.

acid is a proton/H+ donor **and** base is a proton/H+ acceptor;  
H2CO3/CH3COOH **and** NaOH/KOH/Ba(OH)2;

1. Describe **two** different methods, one chemical and one physical, other than measuring the pH, that could be used to distinguish between ethanoic acid and hydrochloric acid solutions of the same concentration.

*Chemical* ***[2 max]***reaction with reactive metal/Mg/Zn/carbonate/hydrogen carbonate;  
hydrochloric acid would react faster/more vigorously / ethanoic acid would  
react slower/less vigorously;

*Physical* ***[2 max]***conductivity;hydrochloric acid will conduct more/higher / ethanoic acid will conductless/lower; 4 max*Accept other suitable examples.*

1. Black coffee has a pH of 5 and toothpaste has a pH of 8. Identify which is more acidic **and** deduce how many times the [H+] is greater in the more acidic product.

black coffee;  
103/1000 times;

1. Define the terms *acid* and *base* according to the Brønsted-Lowry theory. Distinguish between a weak base and a strong base. State **one** example of a weak base.
2. (ii) Weak acids in the environment may cause damage. Identify a weak acid in the environment **and** outline **one** of its effects.

(i) *Acid*: proton/H+ donor **and** *Base:* proton/H+ acceptor;  
*Do not accept OH– for base.*

*Weak base:* (base/electrolyte) partially dissociated/ionized (in  
solution/water) **and** *Strong base:* (base/electrolyte assumed to be  
almost) completely/100% dissociated/ionized (in solution/water) / *OWTTE*;  
NH3 / CH3CH2NH2; 3  
*Allow either name or formula or other suitable example.*

(ii) sulfurous acid/H2SO3;  
corrodes marble/limestone buildings/statues / leaching in soils /  
harms/kills plants;

**OR**

nitrous acid/HNO2;  
corrodes marble/limestone buildings/statues / leaching in soils /  
harms/kills plants;

**OR**

carbonic acid/H2CO3;  
corrodes marble/limestone buildings/statues / acidification of lakes;

1. Describe **two** different properties that could be used to distinguish between a 1.00 mol dm–3 solution of a strong monoprotic acid and a 1.00 mol dm–3 solution of a weak monoprotic acid.

(measuring) the pH / the strong acid solution will have a lower pH;  
conductivity (measurement) / the strong acid will be a better conductor;  
the strong acid will react more vigorously with metals/carbonates / the  
reaction with metals/carbonates;  
the heat change when it is neutralized with a base will be different /  
heat of neutralization

1. Explain, using the Brønsted-Lowry theory, how water can act either as an acid or a base. In **each** case identify the conjugate acid or base formed.

water can act as a Brønsted-Lowry acid by donating a proton/H+ to form OH–;  
water can act as a Brønsted-Lowry base by accepting a proton/H+ to form H3O+

1. Water is an important substance that is abundant on the Earth’s surface. Water dissociates according to the following equation.

H2O(l)  H+(aq) + OH–(aq)

(i) State the equilibrium constant expression for the dissociation of water.

**(1)**

(ii) Explain why even a very acidic aqueous solution still has some OH– ions present in it.

**(1)**

(iii) State and explain the effect of increasing temperature on the equilibrium constant above given that the dissociation of water is an endothermic process.

**(3)**

(iv) The pH of a solution is 2. If its pH is increased to 6, deduce how the hydrogen ion concentration changes.

**(2)**

(i) Kc =  / Kw = [H+][OH–]/Kw = [H3O+][OH–];  
*Do not award mark if [ ] are omitted or other brackets are used.  
Expression must be consistent with K*c*/K*w*.* 1

(ii) [H+]  increases, [OH–] decreases but still some present (*K*w/ *K*c constant) / [OH–]  
cannot go to zero as equilibrium present / [OH–] = , thus [OH–]  
cannot be zero / *OWTTE*;  
*Accept equilibrium present.* 1

(iii) (changing T disturbs equilibrium) forward reaction favoured / equilibrium  
shifts to the right;  
to use up (some of the) heat supplied;  
(*K*w/ *K*c) increases (as both [H+] and [OH–] increase); 3

(iv) pH = 2, [H+] = 0.01 mol dm–3 **and** pH = 6, [H+] = 10–6 mol dm–3 / [H+] = 10–pH;  
[H+] decreased/changed by 10000/10–4

8.

a) The nitrite ion is present in nitrous acid, HNO2, which is a weak acid. The nitrate ion is present in nitric acid, HNO3, which is a strong acid. Distinguish between the terms *strong* and *weak acid* and state the equations used to show the dissociation of each acid in aqueous solution.

**(3)**

(b) A small piece of magnesium ribbon is added to solutions of nitric and nitrous acid of the same concentration at the same temperature. Describe **two** observations that would allow you to distinguish between the two acids.

**(2)**

(c) A student decided to investigate the reactions of the two acids with separate samples of 0.20 mol dm–3 sodium hydroxide solution.

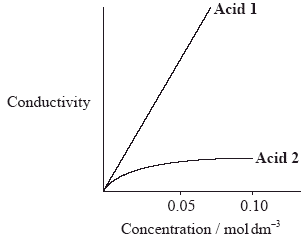
(i) Calculate the volume of the sodium hydroxide solution required to react exactly with a 15.0 cm3 solution of 0.10 mol dm–3 nitric acid.

**(1)**

(ii) The following hypothesis was suggested by the student: “Since nitrous acid is a weak acid it will react with a smaller volume of the 0.20 mol dm–3 sodium hydroxide solution.” Comment on whether or not this is a valid hypothesis.

**(1)**

(d) The graph below shows how the conductivity of the two acids changes with concentration.



Identify **Acid 1** and explain your choice.

**(2)**

(a) strong acid completely dissociated/ionized **and** weak acid partially  
dissociated/ionized;  
HNO3(aq) → H+(aq) + NO3–(aq);  
HNO2(aq)  H+(aq) + NO2–(aq);  
*Allow only arrows as shown.  
State symbols not needed.  
Accept H2O and H3O+*. 3

(b) *With HNO3*:  
faster rate of bubble/gas/hydrogen production;  
faster rate of magnesium dissolving;  
higher temperature change;  
*Accept opposite argument for HNO2.  
Award* ***[1]*** *if 2 observations given but acid is not identified.  
Reference to specific observations needed.* 2 max

(c) (i) (nitric acid) 7.5 cm3; 1

(ii) not valid as nitrous acid reacts with same volume/ 7.5 cm3; 1

(d) HNO3;  
(higher conductivity for solutions with same concentration as) there are  
more ions in solution; 2

9.

(i) Define a Brønsted-Lowry acid.

**(1)**

(ii) Deduce the two acids and their conjugate bases in the following reaction:

H2O(l) + NH3(aq)  OH–(aq) + NH4+(aq)

**(2)**

(iii) Explain why the following reaction can also be described as an acid-base reaction.

F–(g) + BF3(g)  BF4–(s)

(i) donates a proton / H+ ion; 1

(ii) (acid) (conjugate base)  
H2O OH–;  
NH4+ NH3;  
***[1 max]*** *if all four acids and bases given but not clearly paired.* 2

(iii) Lewis acid accepts an electron pair / Lewis base donates an electron pair;  
F– is the base / BF3 is the acid; 2

10. Ethanoic acid, CH3COOH, is a weak acid.

(i) Define the term *weak acid* and state the equation for the reaction of ethanoic acid with water.

**(2)**

(ii) Vinegar, which contains ethanoic acid, can be used to clean deposits of calcium carbonate from the elements of electric kettles. State the equation for the reaction of ethanoic acid with calcium carbonate.

(i) partially dissociated or ionized;  
CH3COOH + H2O  CH3COO– + H3O+ / CH3COOH  CH3COO– + H+;  
* required for mark.* 2

(ii) 2CH3COOH + CaCO3 → Ca(CH3COO)2 + CO2 + H2O

11. The equations of two acid-base reactions are given below.

Reaction **A** NH3(aq) + H2O(l)   + OH–(aq)

The reaction mixture in **A** consists mainly of reactants because the equilibrium lies to the left.

Reaction **B** NH2–(aq) + H2O(l)   + OH–(aq)

The reaction mixture in **B** consists mainly of products because the equilibrium lies to the right.

(i) For each of the reactions **A** and **B**, deduce whether water is acting as an acid or a base and explain your answer.

**(2)**

(ii) In reaction **B**, identify the stronger base, NH2– or OH– and explain your answer.

**(2)**

(iii) In reactions **A** and **B**, identify the stronger acid, NH4+ or NH3 (underlined) and explain your answer.

(i) acid in both reactions;  
because it loses a proton/hydrogen ion/H+ / proton/hydrogen ion/H+ donor;  
*Second mark can be scored if they do not identify it as an acid in  
both reactions.* 2

(ii) NH2–;  
more readily accepts a proton / equilibrium lies to the right /  
takes H+ from H2O;  
*If OH– chosen award* ***[0]*** 2

(iii) NH4+;  
donates a proton more readily than NH3 / equilibrium lies to the left;

12. (a) Describe **two** different experimental methods to distinguish between aqueous solutions of a strong base and a weak base.

**(5)**

(b) Two acidic solutions, **X** and **Y**, of equal concentrations have pH values of 2 and 6 respectively.

(i) Calculate the hydrogen ion concentrations in the two solutions and identify the stronger acid.

**(2)**

(ii) Determine the ratio of the hydrogen ion concentrations in the two solutions **X** and **Y**.

(a) solutions of the same concentration;

pH meter;  
strong base has a higher pH / weak base has lower pH;  
indicator paper/U.I solution;  
strong base has a higher pH/more purple / weak base has lower pH/blue not  
purple / *OWTTE*;  
measuring conductivity (with conductivity meter);  
strong base has a higher conductivity / weak base has lower conductivity;  
comparing heat of neutralization with acid;  
strong base releases more heat / weak base releases less heat;  
*Award* ***[4 max]*** *for two correct methods with expected results.* 5

(b) (i) X;  
[X] = 10–2 (mol dm–3) **and** [Y] = 10–6 (mol dm–3); 2

(ii) 10 000/104 :1;

13. State an equation that shows why rain water is naturally acidic.

CO2 + H2O  H2CO3

14. The two major acids that cause acid rain originate from different sources.

(i) Outline the process responsible for the production of each acid and state an equation to show its formation.

Acid 1:

Acid 2:

(ii) Acid rain has caused damage to limestone buildings and marble statues. State an equation to represent the reaction of acid rain with limestone or marble.

(i) *Acid 1:*(HNO2/HNO3) high temperature in internal combustion/jet engine;  
reaction between N2 and O2 at high temperature/lightning;  
*Accept either of the above for first mark.*

2NO2 + H2O → HNO3 + HNO2 / 4NO2 + O2 + 2H2O → 4HNO3;

*Acid 2:*(H2SO3/H2SO4) from burning of coal / smelting plants / sulfuric  
acid plants / volcanic activity;  
*Do not accept combustion of fossil fuels.*

SO2 + H2O → H2SO3 / SO3 + H2O → H2SO4; 4 max

*Allow H2SO3/H2SO4 to be Acid 1 and HNO2/HNO3 to be Acid 2.*

(ii) CaCO3+ 2HNO3 → Ca(NO3)2 + CO2 + H2O; 1  
Accept equation with H2SO3 or H2SO4 or ionic equations.