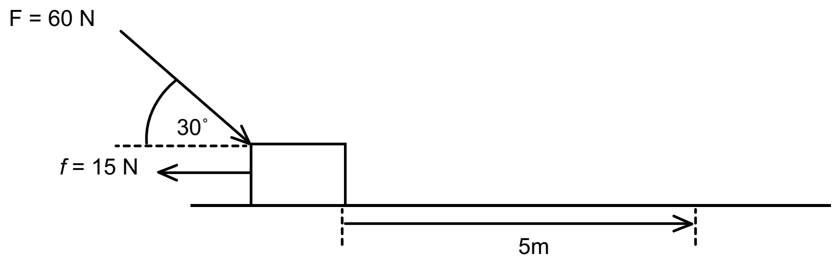
PHYSICAL SCIENCES

Worksheet Booklet

GRADE 12 TERM 2

GRADE 12: WORKSHEET

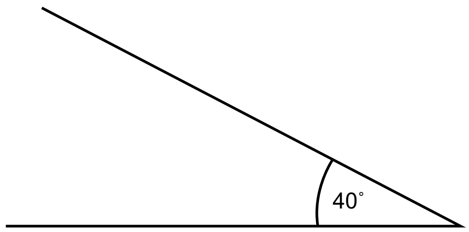
1. The 60 N force is applied to a 10 kg wooden block at an angle of 30° to the horizontal. The coefficient of kinetic friction between the block and the surface is 0,35. The block moves 5 m along a rough horizontal surface.



1.1 Calculate the work done on the block by the 60 N force. (4)

1.2 Calculate the net work done on the block. (6)

2. A skier of mass 87 kg sliding down a ski slope of length 100 m. The force of friction between the skis ans the slope is 220 N.



2.1 Draw a free-body diagram of the forces acting on the skier. Label any relevant angles. (4)

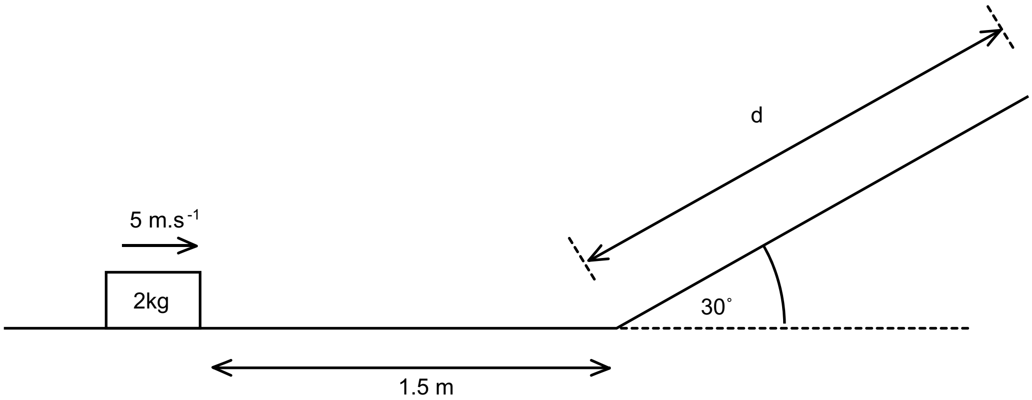
2.2 Calculate the net work done on the skier. (5)

The angle of the slope is now decreased to 20° (the length of the slope is still 100 m) How will the following quantities change? Explain your answer.

2.3 The work done by the friction force. (3)

2.4 The work done by the gravitational force. (3)

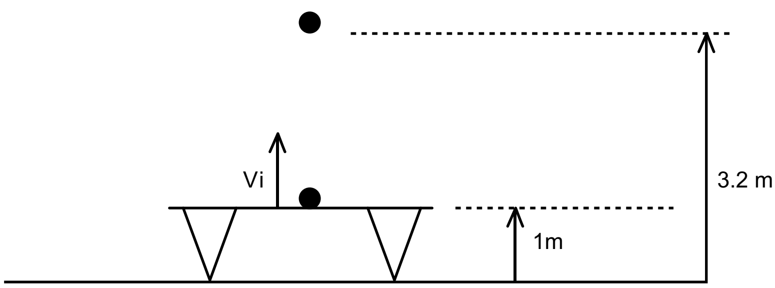
3. A 2 kg block slides at a constant velocity of $5 m.s^{-1}$ along a horizontal surface. It then moves on to a rough surface, causing it to experience a constant frictional force of 15 N. The block slides 1,5 m under the influence of this frictional force before it moves up a frictionless ramp inclined at an angle of 30° to the horizontal, as shown in the diagram below.



3.1 Use the work-energy theorem to determine the speed of the block at the bottom of the ramp. (5)

3.2 Use the work-energy theorem to calculate the distance, d, the block slides up the ramp before coming to rest. (5)

4. A lead ball is dropped onto a trampoline and bounces vertically upwards as shown in the diagram below.

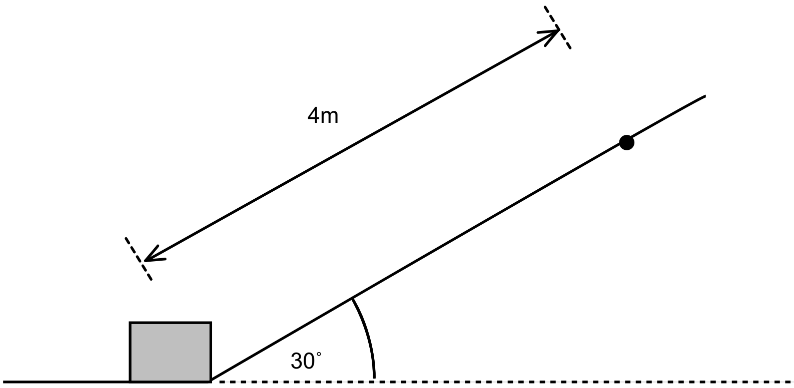


The lead ball leaves the trampoline at a height of 1 m above the ground and reaches a maximum height of 3,2 m. Ignore the effects air resistance.

4.1 State the work-energy theorem in words. (2)

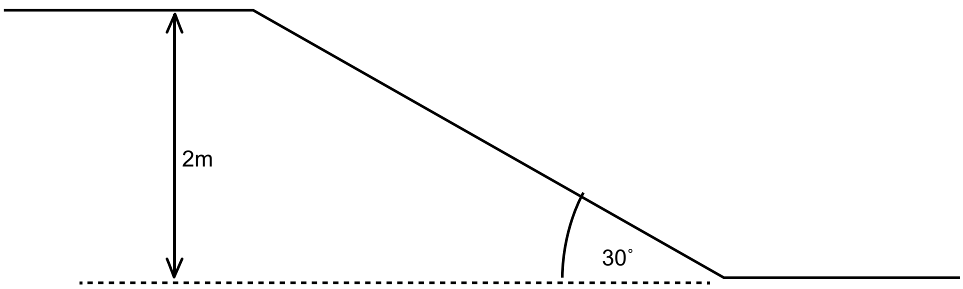
4.2 Use the work-energy theorem to calculate the initial speed v_i with which the lead ball leaves the trampoline. (4)

5. A 15 kg crate is pushed up an inclined ramp with a force of 300 N being applied parallel to the ramp. The ramp is inclined at 30° to the horizontal. The crate experiences a constant frictional force of 95 N.



If the crate started from rest, use energy principles to find the speed of the crate after it is moved 4 m along the ramp. (6)

6. A 75 kg skier moving at $8 m.s^{-1}$ coasts up a 2 m high rise as shown in the diagram below. The skier experiences a frictional force of 100 N between her skis and the snow.



Use energy principles to calculate her speed at the top of the slope. (6)

7. A winch pulls a crate of mass 400 kg at constant speed of $1,6 m.s^{-1}$ along a rough horizontal surface. The power output of the winch is 3,4 kW.

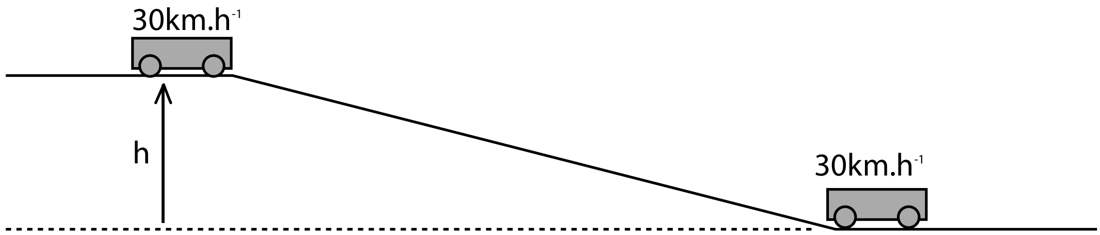
7.1 Calculate the magnitude of the applied force of the winch. (3)

7.2 Determine the magnitude of the frictional force acting on the crate. (1)

The same winch now pulls the crate up a rough plane inclined at 10° to the horizontal. The frictional force acting on the crate is now 2 090 N.

7.3 Calculate the maximum constant speed reached by the crate if the power output of the winch remains unchanged. (5)

8. An 8 000 kg truck drives up an inclined road of length 40 m at a constant speed of $30 km.h^{-1}$. The total work done by the engine on the truck over the 40 m is 800 000 J. The work done to overcome friction is 95 000 J.



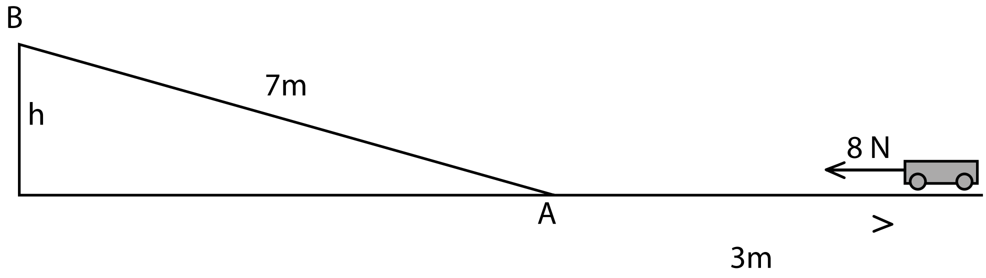
8.1 Calculate the height, h, reached by the truck at the top of the road. (6)

8.1 The average power delivered by the truck's engine. (6)

TOPIC 5: Work, energy and power

GRADE 12: CONSOLIDATION QUESTIONS — TOTAL: 46 MARKS

1. A 2 kg trolley is at rest on a horizontal frictionless surface. A constant horizontal force of 8 N is applied to the trolley over a distance of 3 m.



When the force is removed at point A, the trolley moves a distance of 7 m up the incline until it reaches the maximum height at point A. While the trolley moves up the incline, there is a constant frictional force of 1,5 N acting on it.

1.1 Write down the name of a non-conservative force acting on the trolley as it moves up the incline. (1)

1.2 Draw a labelled free-body diagram showing all the forces acting on the trolley as it moves along the horizontal surface. (3)

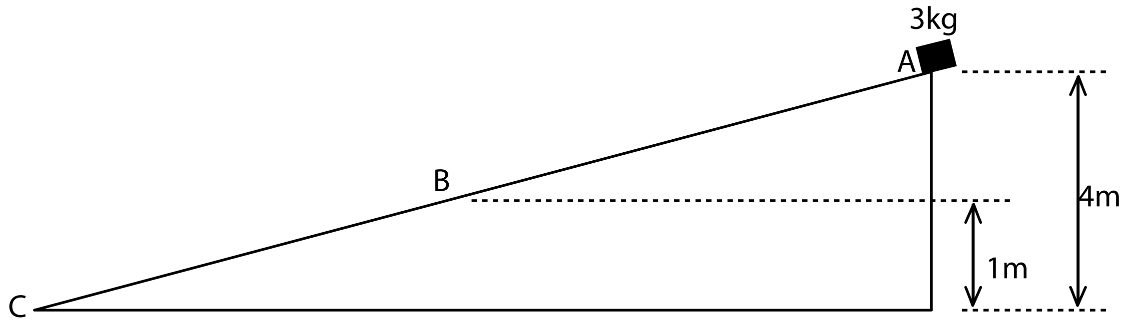
1.3 State the work-energy theorem in words. (2)

1.4 Use the work-energy theorem to calculate the speed of the trolley when it reaches point A. (4)

1.5 Calculate the height, h, that the trolley reaches at point B. (5)

[15]

2. A 3 kg block moves from rest down path ABC as shown below. Section AB of the path is frictionless. Assume that the block moves in a straight line down the path.



2.1 State, in words, the principle of conservation of mechanical energy. (2)

2.2 Use the principle of conservation of mechanical energy to calculate the speed of the block when it reaches point B. (4)

On reaching point B, the block continues to move down section BC of the path. It experiences an average frictional force of 8 N and reaches point C at a speed of $3 m.s^{-1}$.

2.3 Apart from friction, write down the name of two other forces that act on the block while it moves down section BC. (2)

2.4 In which direction does the net force act on the block as it moves down section BC? (1)

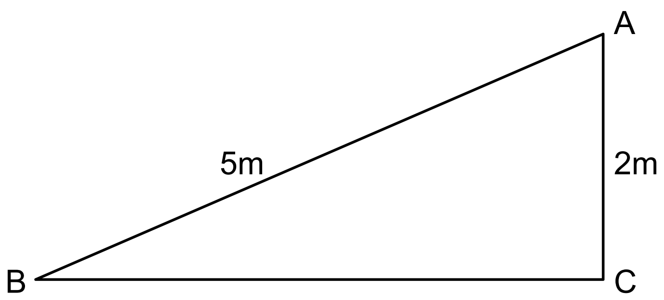
2.5 Use the work-energy theorem to calculate the length of section BC. (5)

Another crate of mass 20 kg now moves from point A down path ABC.

2.6 How will the velocity of this 20 kg crate at point B compare to that of the 3 kg crate at B? Write down only greater than, smaller than or equal to. (1)

[15]

3. The diagram below shows a slide AB at a playground. The slide is 5 m long and 2 m high. A boy of mass 45 kg and a girl of mass 25 kg stand at the top of slide at A. The girl accelerates uniformly from rest down the slide. She experiences a constant frictional force of 40 N. The boy falls vertically down from the top of the slide through height AC of 2 m. Ignore the effects of air friction.



3.1 Write down the principle of conservation of mechanical energy in words. (2)

3.2 Draw a labelled free-body diagram to show ALL the forces acting on the:

3.2.1 Boy while falling vertically downwards. (1)

3.2.2 Girl as she slides down the slide. (3)

3.3 Use the principle of conservation of mechanical energy to calculate the speed of the boy when he reaches the ground at C. (4)

3.4 Use the work-energy theorem to calculate the speed of the girl when she reaches the end of the slide at B. (5)

3.5 How would the velocity of the girl at B compare to that of the boy at C if the slide exerts no frictional force on the girl? Write down only greater than, less than or equal to. (1)

[16]

GRADE 12: WORKSHEET MEMORANDUM

1.1 $W_F = F\Delta x \cos\theta = (60✓)(5✓)\cos 30^o✓ = +259,81 J✓$ (4)

1.2 $F_y = F\cos 60^o = (60).\cos 60^o = 30 N \text{ down}✓$

$W = mg = (10)(9,8) = 98 N \text{ down}✓$

$F_{downonground} = 98 + 30 = 128 N \text{ down}$

$N = 128 N \text{ up}✓$

$f_k = \mu_k N = (0,35)(128) = 44,8 N✓$

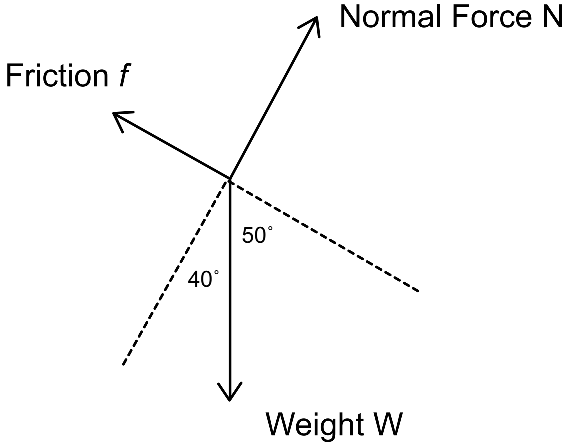
$W_{net} = W_F + W_f$

$W_{net} = +259,81 + f\Delta x \cos 180^o$

$W_{net} = +259,81 + (15)(5)(-1)✓$

$W_{net} = +259,81 - 75 = +184,81 J✓$ (6)

2.1



(4)

2.2 $W_{net} = W_W + W_f$

$W_{net} = W\Delta x \cos\theta + f\Delta x \cos\theta$

$W_{net} = (852,6✓)(100)\cos 50^o✓ + (220✓)(100)\cos 180^o✓$

$W_{net} = +54\,804,07 - 22\,000$

$W_{net} = +32\,804,07 J✓$ (5)

2.3 The normal force N acting on the skier will increase ✓ ($W_y = W\cos 20^o$)
The frictional force will increase ✓ ($f_k = \mu_k N$)
Work done by friction will increase ✓ (3)

2.4 $W_W = W\Delta x \cos\theta$

The angle θ between the displacement and the weight increases ✓ from 50° to 70°

$\cos\theta$ decreases✓

Work done by the gravitational force will decrease• (3)

3.1 $W_{net} = \Delta E_k$

$W_{net} = E_{kf} - E_{ki}$

$W_f = \frac{1}{2}mv_f^2 - \frac{1}{2}mv_i^2$

$f\Delta x\, cos\theta = \frac{1}{2}mv_f^2 - \frac{1}{2}mv_i^2$

$(15✓)(1,5)\cos 180°✓ = \frac{1}{2}(2)v_f^2✓ - \frac{1}{2}(2)(5)^2✓$

$-22,5 = v_f^2 - 25$

$v_f^2 = 2,5$

$v_f = 1,58\,m.s^{-1}✓$ (5)

3.2 $W_{net} = \Delta E_k$

$W_{net} = E_{kf} - E_{ki}$

$W_W = \frac{1}{2}mv_f^2 - \frac{1}{2}mv_i^2$

$W\Delta x\, cos\theta = \frac{1}{2}mv_f^2 - \frac{1}{2}mv_i^2$

$(19,6✓)d.\,cos\,180°✓ = 0✓ - \frac{1}{2}(2)(1,58)^2✓$

$-19,6d = -2,5$

$d = 0,13\,m✓$ (5)

4.1 The net work done on an object is equal to the change in the object's kinetic energy ✓✓ (2)

4.2 $W_{net} = \Delta E_k$

$W_{net} = E_{kf} - E_{ki}$

$W_W = \frac{1}{2}mv_f^2 - \frac{1}{2}mv_i^2$

$W\Delta x\, cos\theta = \frac{1}{2}mv_f^2 - \frac{1}{2}mv_i^2$

$m(9,8)(2,2✓)\cos 180° = 0✓ - \frac{1}{2}mv_i^2$

$-21,56m = -0,5mv_i^2$

$-21,56 = -0,5v_i^2✓$

$v_i^2 = 43,12$

$v_i = 6,57m.s^{-1}✓$ (4)

5.

$sin30^o = \frac{h}{4}$

$h = 4 sin30^o = 2m\checkmark$

$W_{nc} = \Delta E_p + \Delta E_k$

$W_F + W_f = (E_{pf} - E_{pi}) + (E_{kf} - E_{ki})$

$(300)(4)cos0^o\checkmark + (95)(4)cos180^o\checkmark = [(15)(9,8)h - 0]\checkmark + [\frac{1}{2}(15)v_f^2 - 0]\checkmark$

$1200 - 380 = [(15)(9,8)(2)] + [\frac{1}{2}(15)v_f^2]$

$820 = 294 + 7,5v_f^2$

$526 = 7,5v_f^2$

$v_f^2 = 70,13$

$v_f = 8,37 m.s^{-1}\checkmark$ (6)

6.

$sin30^o = \frac{2}{\Delta x}$

$\Delta x = \frac{2}{(sin30^o)} = 4m\checkmark$

$W_{nc} = \Delta E_p + \Delta E_k$

$W_f = (E_{pf} - E_{pi}) + (E_{kf} - E_{ki})$

$(100)(4)cos180^o\checkmark = [(75)(9,8)(2) - 0]\checkmark + [\frac{1}{2}(75)v_f^2\checkmark - \frac{1}{2}(75)(8)^2\checkmark]$

$-400 = 1470 + 37,5v_f^2 - 2\,400$

$530 = 37,5v_f^2$

$v_f^2 = 14,13$

$v_f = 3,76 m.s^{-1}\checkmark$ (6)

7.1 $P = Fv_{av}$

$F = \frac{P}{v_{av}} = \frac{3\,400\checkmark}{1,6\checkmark} = 2\,125 N\checkmark$ (3)

7.2 $f = 2\,125 N\checkmark$ (1)

7.3 $W_x = W sin10^o = (400)(9,8)sin10^o\checkmark = 680,7 N\checkmark$ down the slope

$F_{down the slope} = W_x + f = 680,7 + 2\,090 = 2\,770,7 N\checkmark$ down the slope

$P_{av} = Fv_{av}$

$v_{av} = \frac{P_{av}}{F} = \frac{3\,400\checkmark}{2\,770,7} = 1,23 m.s^{-1}\checkmark$ (5)

8.1 $W_{nc} = \Delta E_p + \Delta E_k$

$W_F + W_f = (E_{pf} - E_{pi}) + (E_{kf} - E_{ki})$

$800\,000\checkmark - 95\,000\checkmark = [(8\,000)(9,8)h\checkmark - 0\checkmark] + 0\checkmark$

$705\,000 = 78\,400h$

$h = 8,99 m\checkmark$ (6)

8.2 $30\,km.h^{-1} = 8,33\,m.s^{-1}$✓

$W_F = F\Delta x \cos\theta$

$800\,000$✓ $= F.(40$✓$)\cos 0°$

$F = 20\,000\,N$✓ up the slope

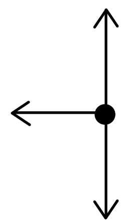
$P_{av} = Fv_{av} = (20\,000)(8,33)$✓ $= 166\,600\,W$✓ (6)

TOPIC 5: Work, energy and power

GRADE 12: CONSOLIDATION QUESTIONS MEMORANDUM TOTAL: 46 MARKS

1.1 Friction ✓ (1)

1.2



(3)

1.3 The net work done on an object is equal to the change in the object's kinetic energy ✓✓ (2)

1.4 $W_{net} = \Delta E_k$

$F_{net}\Delta x \cos\theta = \frac{1}{2}mv_f^2 - \frac{1}{2}mv_i^2$

$(8)(3)\cos 0° ✓ = \frac{1}{2}mv_f^2 - 0 ✓$

$(8)(3)\cos 0° = \frac{1}{2}(2 ✓)v_f^2$

$24 = v_f^2$

$v_f = 4,90\ m.s^{-1}$ ✓ (4)

1.5 $W_{nc} = \Delta E_p + \Delta E_k$

$W_{friction} = \Delta E_p + \Delta E_k$

$f\Delta x \cos\theta = (E_{pf} - E_{pi}) + (E_{kf} - E_{ki})$

$(1,5)(7)\cos 180° ✓ = [(2)(9,8)h - 0] ✓ + [0 - (\frac{1}{2}(2)(4,9)^2)] ✓$

$-10,5 ✓ = 19,6h - 24$

$13,5 = 19,6h$

$h = 0,69\ m$ ✓ (5)

2.1 The total amount of mechanical energy, in a closed system in the absence of dissipative forces (e.g. friction, air resistance), remains constant. ✓✓ (2)

2.2 $E_{mech\ at\ A} = E_{mech\ at\ B}$

$E_{p\ at\ A} + E_{k\ at\ A} = E_{p\ at\ B} + E_{k\ at\ B}$

$(3)(9,8)(4) ✓ + 0 = (3)(9,8)(1) + \frac{1}{2}(3)v^2 ✓$

$117,6 = 29,4 + 1,5v^2$

$v_B = 7,67\ m.s^{-1}$ ✓ (4)

2.3 Gravitational force ✓ (weight) and the normal force ✓ (2)

2.4 Up the slope ✓ (1)

2.5 $W_{net} = \Delta E_k$

$W_W + W_f = E_{kf} - E_{ki}$

$mg\Delta y \cos 0^\circ + f\Delta x \cos 180^\circ = \frac{1}{2}mv_f^2 - \frac{1}{2}mv_i^2$

$(3)(9,8)(1)\cos 0^\circ ✓ + (8)\Delta x \cos 180^\circ ✓ = \frac{1}{2}(3)(3)^2 ✓ - \frac{1}{2}(3)(7,67)^2 ✓$

$29,4 - 8\Delta x = 13,5 - 88,24$

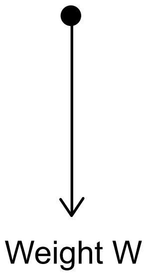
$-8\Delta x = -104,14$

$\Delta x = 13,02\,m ✓$ (5)

2.6 Equal to ✓ (The speed at B is independent of mass) (1)

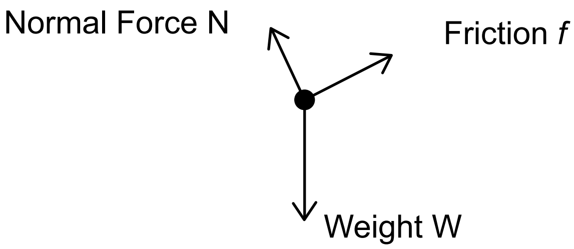
3.1 The total amount of mechanical energy, in a closed system in the absence of dissipative forces (e.g. friction, air resistance), remains constant. ✓✓ (2)

3.2.1



(1)

3.2.2



(3)

3.3 $E_{mech\,at\,A} = E_{mech\,at\,C}$

$E_{p\,at\,A} + E_{k\,at\,A} = E_{p\,at\,C} + E_{k\,at\,C}$

$(45)(9,8)(2) ✓ + 0 = 0 + \frac{1}{2}(45)v^2 ✓$

$882 ✓ = 22,5v^2$

$v_C = 6,26\,m.s^{-1} ✓$ (4)

3.4 $W_x = W\sin 40° = (25)(9,8)\sin 40° = 157,48\text{ N}$ ✓ down the slope

$W_{net} = \Delta E_k$

$F_{net}\Delta x\cos\theta = \frac{1}{2}mv_f^2 - \frac{1}{2}mv_i^2$

$(W_x - f)(5)\cos 0° = \frac{1}{2}(25)v_f^2 - 0$

$(157 - 40✓)(5✓)\cos 0° = \frac{1}{2}(25)v_f^2✓ - 0$

$(157,48)(5)\cos 0° = \frac{1}{2}(25)v_f^2$

$787,4 = \frac{1}{2}(25)v_f^2$

$v_f^2 = 62,992$

$v_f = 7,94\text{ m.s}^{-1}$ ✓ (5)

3.5 Equal to✓ (1)

GRADE 12: WORKSHEET

1. An emergency vehicle travelling down a road at constant speed emits sound waves from its siren. A man stands on the side of the road with a detector which registers sound waves at a frequency of 1 500 Hz as the vehicle approaches him. After passing him, and moving away at the same constant speed, sound waves of frequency 1 350 Hz are registered. Assume that the speed of sound in air is $340\,m.s^{-1}$.

   1.1 State the Doppler Effect in words. (2)

   1.2 Explain why the observed frequency of the siren decreases as it passes the man. (2)

   1.3 Calculate the speed at which the emergency vehicle is moving. (7)

   1.4 Calculate the frequency at which the siren emits the sound waves. (3)

2. During an experiment to determine the speed of sound, learners are given a car with a hooter that sounds a single note of frequency 450 Hz. They drive the car at constant speed past a stationary tape recorder which is mounted in the middle of the road. Ignore the effects of friction. The tape recorder records the sound of the cars hooter.

   The learners make the following observation:

   The pitch of the sound from the hooter as it moved towards the tape recorder was higher than the pitch as the siren moved away from the recorder.

   2.1 Name the effect which explains this observation. (2)

   In one of the tests the speed of the car was recorded as $39{,}83\,km.h^{-1}$. Two notes from the hooter were recorded: one with a frequency of 465 Hz and the other note with a frequency lower than 450 Hz.

   2.2 Convert $39{,}83\,km.h^{-1}$ to $m.s^{-1}$. (2)

   2.3 Determine the speed of sound in air. (5)

   2.4 Give a reason why the observed frequencies are respectively higher and lower than the frequency of the source. (2)

3. A stationary car is parked on the side of the road. Its alarm emits sound waves of frequency 800 Hz. The driver of a bus approaching the car and passing it at constant speed, observes the frequency of the emitted sound waves to change by 100 Hz.

   3.1 Name and state the wave phenomenon illustrated above. (3)

   3.2 Take the speed of sound in air as $340\,m.s^{-1}$ and calculate the speed at which the bus passes the stationary car. (5)

4. The siren of an emergency vehicle produces a sound of frequency 900 Hz. A woman sitting next to the road notices that the pitch of the sound changes as the vehicle moves towards and then away from her.

   4.1 Write down the name of the above phenomenon. (1)

   4.2 Assume that the speed of sound in air is $340\,m.s^{-1}$. Calculate the frequency of the sound of the siren observed by the woman, when the vehicle is moving towards her at a speed of $30\,m.s^{-1}$. (4)

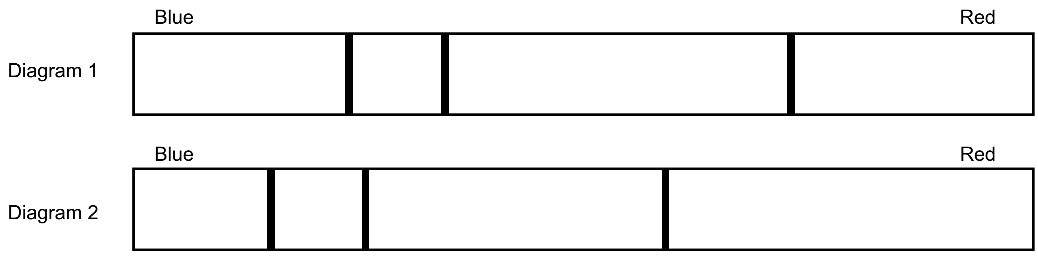
4.3 The vehicle moves away from the woman at constant velocity, then speeds up.

4.3.1 How will the observed frequency compare with the original frequency of the siren when the vehicle moves away from the woman at constant velocity? Write only GREATER THAN, SMALLER THAN or EQUAL TO. (2)

4.3.2 How will the observed frequency change as the vehicle speeds up whilst moving away? Write only INCREASES, DECREASES or REMAINS THE SAME. (2)

5. A study of spectral lines obtained from various stars can provide valuable information about the movement of the stars.

The two diagrams below represent different spectral lines of an element. Diagram 1 represents the spectrum of the element in a laboratory on Earth. Diagram 2 represents the spectrum of the same element from a distant star.



5.1 Is the star moving towards or away from the Earth? (1)

5.2 Explain the answer by referring to the shifts in the spectral lines in the two diagrams above. (3)

6. An observation of the spectrum of a distant star shows that it is moving away from the Earth.

Explain, in terms of the frequencies of the spectral lines, how it is possible to conclude that the star is moving away from the Earth. (2)

7. Briefly explain the observations that enable scientists to tell that the universe is expanding. (3)

8. Spectral lines of star X at an observatory are observed to be red shifted.

8.1 Explain the term red shifted in terms of wavelength. (2)

8.2 Will the frequency of the light observed from the star INCREASE, DECREASE or REMAIN THE SAME? (1)

TOPIC 6: Doppler Effect

GRADE 12: CONSOLIDATION QUESTIONS — TOTAL: 34 MARKS

1. An ambulance approaches a stationary observer at a constant speed of $10,6\,m.s^{-1}$, while its siren produces sound at a constant frequency of 954,3 Hz. The stationary observer measures the frequency of the sound as 985 Hz.

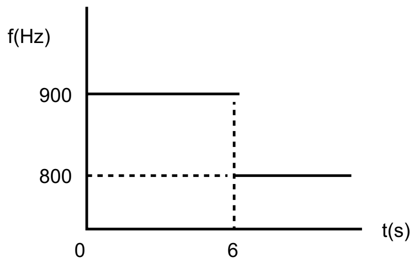
1.1 Name the medical instrument that makes use of the Doppler Effect. (1)

1.2 Calculate the velocity of sound. (5)

1.3 How would the wavelength of the sound wave produced by the siren of the ambulance change if the frequency of the wave were higher than 954,3 Hz? Write down only increases, decreases or stays the same. (1)

1.4 Give a reason for the answer to question 1.3. (2)

2. The siren of an ambulance emits sound waves at a frequency of 850 Hz. An observer, travelling in a car at a constant speed in a straight line, begins measuring the frequency of the sound waves emitted by the siren when he is at a distance x from the ambulance. The observer continues measuring the frequency as he approaches, passes and moves away from the ambulance. The results obtained are shown in the graph below.



2.1 Give a reason for the sudden change in the observed frequency at t = 6s. (1)

2.2 Calculate the:

2.2.1 Speed of the car. Take the speed of sound in air as $340\,m.s^{-1}$. (5)

2.2.2 The distance x between the car and the ambulance when the observer begins measuring the frequency. (3)

3. The siren of a stationary police car emits sound waves of wavelength 0,55 m. With its siren on, the police car now approaches a stationary listener at a constant velocity on a straight road. Assume that the speed of sound in air is $345\,m.s^{-1}$.

3.1 Will the wavelength of the sound waves observed by the listener be greater than, smaller than or equal to 0,55 m? (1)

3.2 Name the phenomenon observed in question 3.1 (1)

3.3 Calculate the frequency of sound waves observed by the listener if the car approaches him at a speed of $120\,km.h^{-1}$. (7)

3.4 How will the answer to question 3.3 change if the police car moves away from the listener at $120\,km.h^{-1}$? Write down only increases, decreases or remains the same. (1)

4. Dolphins use ultrasound to scan their environment. When a dolphin is 100 m from a rock, it emits ultrasound saves of frequency 250 kHz. Whilst swimming at $20\,m.s^{-1}$ towards the rock. Assume the speed of sound in water is $1500\,m.s^{-1}$.

4.1 Calculate the frequency of the sound waves detected on the rock. (4)

4.2 When the dolphin is 50 m from the rock, another ultrasound wave of 250 kHz is emitted. How will the frequency of the detected sound waves compare with the answer calculated in question 4.1? Write down only higher, lower or remains the same. Explain your answer. (2)

GRADE 12: WORKSHEET MEMORANDUM

1.1 The apparent change in frequency of a source when there is relative motion between the source and the observer. ✓✓ (2)

1.2 The wave fronts are stretched out. Wavelength increases. ✓ Frequency is inversely proportional to wavelength. ✓ Frequency decreases. (2)

1.3 Approaching the man:

$$f_L = \frac{v \pm v_L}{v \pm v_s} f_s \checkmark$$

$$1500 = \frac{340}{340 - v_s \checkmark} f_s$$

$$(1500)(340 - v_s) = 340 f_s$$

$$f_s = \frac{(1500).(340 - v_s)}{340} \checkmark$$

Moving away from man:

$$f_L = \frac{v \pm v_L}{v \pm v_s} f_s$$

$$1350 = \frac{340}{340 + v_s \checkmark} f_s$$

$$(1350)(340 + v_s) = 340 f_s$$

$$f_s = \frac{(1350)(340 + v_s)}{340} \checkmark \qquad \text{(ii)}$$ (7)

Equate (i) and (ii)

$$\frac{(1500)(340 - v_s)}{340} = \frac{(1350)(340 + v_s)}{340} \checkmark$$

$$(1500)(340 - v_s) = (1350)(340 + v_s)$$

$$510\,000 - 1500 v_s = 459\,000 + 1350 v_s$$

$$51000 = 2\,850 v_s$$

$$v_s = 17{,}89\,m.s^{-1} \checkmark$$

1.4 $$f_s = \frac{(1500)(340 - 17{,}89)}{340} = 1421\,Hz \checkmark$$ (3)

2.1 Doppler Effect ✓✓ (2)

2.2 $$39{,}83\,km.h^{-1} = \frac{39{,}83}{3{,}6 \checkmark} = 11{,}06\,m.s^{-1} \checkmark$$ (2)

2.3 $$f_L = \frac{v \pm v_L}{v \pm v_s} f_s \checkmark$$

$$465 \checkmark = \frac{v}{v - 11{,}06 \checkmark} (450 \checkmark)$$

$$465(v - 11{,}06) = 450v$$

$$465v - 5\,142{,}9 = 450v$$

$$15v = 5\,142{,}9$$

$$v = 342{,}86\,m.s^{-1} \checkmark$$ (5)

2.4 When the car is approaching the listener, the waves in front of the source are compressed, wavelength decreases and frequency increases. ✓

When the car is moving away from the listener, the waves behind the source are longer, wavelength increases and frequency decreases. ✓ (2)

3.1 The Doppler Effect. ✓

The apparent change in frequency of a source when there is relative motion between the source and the observer. ✓✓ (3)

3.2 Approaching the car:

$f_L = \frac{v \pm v_L}{v \pm v_s} f_s$ ✓

$f_L = \frac{v + v_L}{v} f_s$

850✓ $= \frac{340 + v_L}{340}$✓ $(800$✓$)$

$850(340) = 800(340 + v_L)$

$289\,000 = 272\,000 + 800.v_L$

$17\,000 = 800v_L$

$v_L = 21{,}25\ m.s^{-1}$ ✓

OR

Moving away from the car:

$f_L = \frac{v \pm v_L}{v \pm v_s} f_s$ ✓

$f_L = \frac{v - v_L}{v} f_s$

750✓ $= \frac{340 - v_L}{340}$✓ $(800$✓$)$

$750(340) = 800(340 - v_L)$

$255\,000 = 272\,000 - 800v_L$

$-17\,000 = -800v_L$

$v_L = 21{,}25\ m.s^{-1}$ ✓ (5)

4.1 The Doppler Effect ✓ (1)

4.2 $f_L = \frac{v \pm v_L}{v \pm v_s} f_s$ ✓

$f_L = \frac{v}{v - v_s} f_s$

$f_L = \frac{340}{340 - 30}$✓ $(900$✓$) = 987{,}10\ Hz$✓ (4)

4.3.1 Smaller than ✓✓ (2)

4.3.2 Decreases ✓✓ (2)

5.1 Towards the Earth. ✓ (1)

5.2 The spectral lines are shifted towards the blue end of the visible spectrum. ✓ The wavelengths of the light emitted for the star is shorter ✓ than expected. According to the Doppler Effect the waves in front of the moving star will be compressed. ✓ (3)

6. If the star is moving away from Earth, then the wavelengths of the spectral lines emitted by the star will be longer than expected. ✓ The frequency of the emitted light will be higher than expected. ✓ (2)

7. Galaxies that are moving away from Earth emit light in which the spectral lines are shifted towards the red end ✓ of visible spectrum. According to the Doppler Effect, these longer wavelengths ✓ of light indicate that the galaxy is moving away from Earth. ✓ (3)

8.1 The spectral lines are shifted towards the red end ✓ of the visible spectrum. The wavelength of the light emitted by the star is longer ✓ than expected. (2)

8.2 Decrease ✓ (1)

TOPIC 6: Doppler Effect

GRADE 12: CONSOLIDATION QUESTIONS MEMORANDUM — TOTAL: 34 MARKS

1.1 Doppler flow meter ✓ (1)

1.2 $f_L = \frac{v \pm v_L}{v \pm v_s} f_s$ ✓

$985✓ = \frac{v}{v - 10,6✓}(954,3✓)$

$985(v - 10,6) = 954,3v$

$985v - 10\,441 = 954,3v$

$30,7v = 10\,441$

$v = 340,10\ m.s^{-1}$ ✓ (5)

1.3 Decreases ✓ (1)

1.4 Wavelength is inversely proportional ✓ to frequency at constant speed ✓ (2)

2.1 The observer is approaching the siren (frequency is higher than 850 Hz), passes it and moves away (frequency is lower than 850 Hz). ✓ (1)

2.2.1 $f_L = \frac{v \pm v_L}{v \pm v_s} f_s$ ✓

$900✓ = \frac{340 + V_L✓}{340}(850✓)$

$850(340 + v_L) = 340(900)$

$289\,000 + 850v_L = 306\,000$

$850v_L = 17\,000$

$v_L = 20\ m.s^{-1}$ ✓ (5)

2.2.2 $\Delta x = v.\Delta t = (20✓)(6✓) = 120\ m$✓ (3)

3.1 Smaller than ✓ (1)

3.2 Doppler Effect ✓ (1)

3.3 $120\ km.h^{-1} = 33,33\ m.s^{-1}$ ✓

$f_s = \frac{v}{\lambda} = \frac{345}{0,55} = 627,27\ Hz$✓

$f_L = \frac{v \pm v_L}{v \pm v_s} f_s$ ✓

$f_L = \frac{345✓}{345 - 33,33✓}(627,27✓)$

$f_L = \frac{345}{311,67}(627,27)$

$f_L = 694,35\ Hz$✓ (7)

3.4 Decreases ✓ (1)

4.1 $f_L = \frac{v \pm v_L}{v \pm v_s} f_s$ ✓

$f_L = \frac{1500}{1500 - 20✓}(250\,000✓)$

$f_L = \frac{1500}{1480}(250\,000)$

$f_L = 253\,378,38\ Hz$✓ (4)

4.2 Remains the same ✓

The observed frequency does not depend on distance ✓ (2)

GRADE 12: WORKSHEET

MULTIPLE CHOICE

1. The rate of a chemical reaction is most correctly defined as the ...
   - A time taken for a reaction to occur.
   - B speed at which a reaction takes place.
   - C change in the amount of reactants or products.
   - D change in the concentration of reactants or products per unit time. (2)

2. A catalyst is a substance that increases the rate of a chemical reaction by:
   - A Increasing the activation energy for the reaction.
   - B Decreasing the activation energy for the reaction.
   - C Increasing the average kinetic energy of the reacting particles.
   - D Decreasing the average kinetic energy of the reacting particles. (2)

3. In a series of experiments 0,05 g samples of magnesium were added separately to $100\ cm^3$ volumes of hydrochloric acid. The table below summarises the experimental conditions:

Expt	Mg(s)	$[HCl(aq)]\ mol.dm^{-3}$	Temp of acid (°C)
I	Ribbon	0,1	25
II	Ribbon	0,5	25
III	Powder	0,1	70
IV	Powder	0,5	25
V	Powder	0,1	20

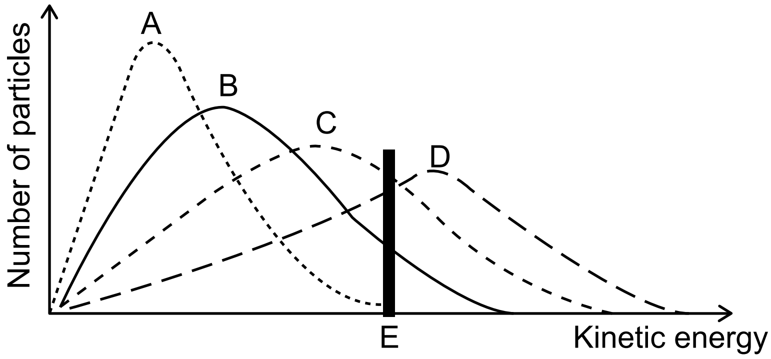
In which of the experiments would the magnesium be expected to take the shortest time to react completely with the excess hydrochloric acid?

A. I and II B. III and IV

C. III and V D. II and IV (2)

4. A test tube contains 4 g of zinc powder covered with $20\ cm^3$ of a $0,01 mol.dm^{-3}$ hydrochloric acid solution. A second test tube contains 8 g of zinc pellets covered with $25\ cm^3$ of a $0,05\ mol.dm^{-3}$ nitric acid solution. What could possibly cause the reaction in the second test tube to take place at a faster rate?
   - A The volume of the acid in the second test tube is greater
   - B The nitric acid has a higher concentration
   - C The zinc pellets have a greater mass
   - D The surface area of the zinc pellets is greater than that of the powder (2)

5. The Maxwell-Boltzmann energy distribution curves below show the number of particles as a function of their kinetic energy for a reaction at four different temperatures. The minimum kinetic energy needed for effective collisions to take place is represented by E.



Which ONE of these curves represents the reaction with the highest rate?

A. A

B. B

C. C

D. D (2)

LONG QUESTIONS

1. When manganese (IV) oxide catalyst is added to hydrogen peroxide, water and oxygen are produced according to the following equation:

$$2H_2O_2 \longrightarrow 2H_2O + O_2$$

The reaction rate was measured when 1g of manganese (IV) oxide was added to $100\,cm^3$ of hydrogen peroxide. If the following changes are made, how will the reaction rate change?

1.1 Heat the hydrogen peroxide (1)

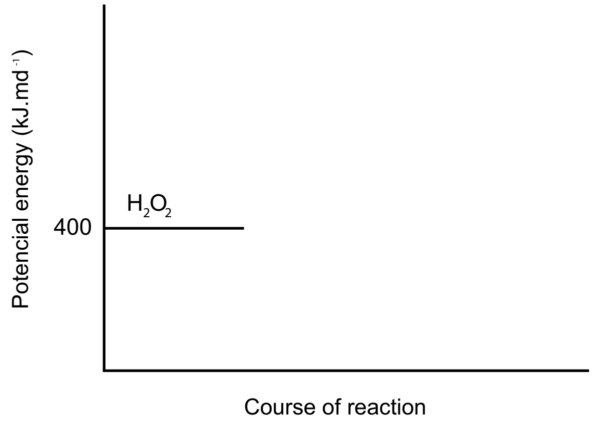
1.2 The manganese (IV) oxide catalyst is crushed into a fine powder (1)

The activation energy (EA) for this reaction is 75 kJ and the heat of reaction (ΔH) is –196 kJ.

1.3 Define the term activation energy. (2)

1.4 Redraw the set of axes below and then complete the potential energy diagram for this reaction. Indicate the value of the potential energy of the following on the y-axis:

- Activated complex
- Products (3)



When powdered manganese dioxide is added to the reaction mixture, the rate of the reaction increases.

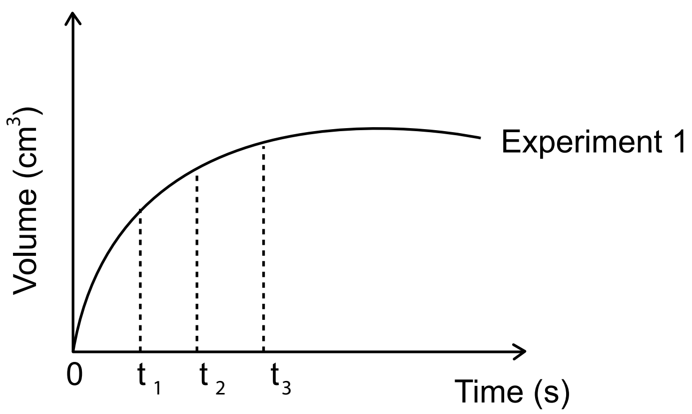
1.5 On the graph drawn for question 1.4, use broken lines to show the path of the reaction when the manganese(IV)oxide is added. (2)

1.6 Use the collision theory to explain how manganese(IV)oxide influences the rate of decomposition of hydrogen peroxide. (3)

2. Dilute acids, indicated in the table below, react with EXCESS zinc in each of the three experiments to produce hydrogen gas. The zinc is completely covered with the acid in each experiment.

Experiment	Dilute acid
Experiment 1	$100\,cm^3$ of $0,1 mol.dm^{-3}$ of H_2SO_4
Experiment 2	$50\,cm^3$ of $0,2 mol.dm^{-3}$ of H_2SO_4
Experiment 3	$100\,cm^3$ of $0,1 mol.dm^{-3}$ HCl

The volume of hydrogen gas produced is measured in each experiment and the graph of experiment 1 was drawn as shown below.



2.1 At which time (t_1, t_2 or t_3) is the:

2.1.1 reaction rate the highest (1)

2.1.2 mass of zinc present in the flask the smallest. (1)

2.2 Why does the graph flatten out after t_3? (2)

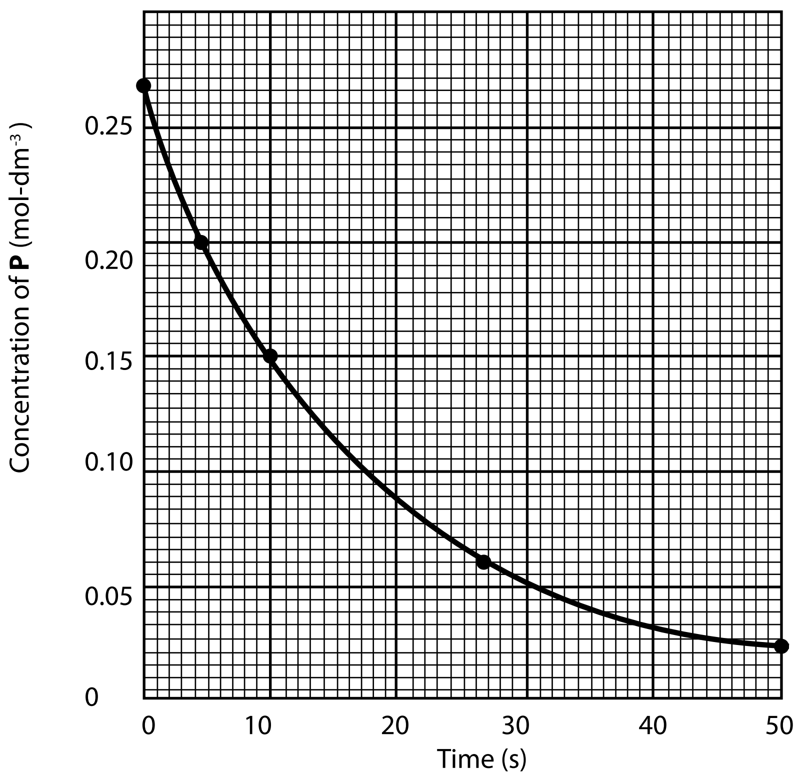
2.3 In which time interval, between t_1 and t_2 OR between t_2 and t_3 does the largest volume of hydrogen gas form per second? (2)

2.4 Redraw the graph for experiment 1. On the same set of axes, sketch the graphs that will be obtained for experiments 2 and experiments 3 using the information from the table above. Label each graph Experiment 1, Experiment 2 and Experiment 3 (4)

3. The graph below shows the decomposition of gas P according to the following equation:

$$P(g) \longrightarrow 2Q(g) + R(g) \qquad \Delta H < 0$$

Graph of concentration of P versus time



3.1 Define the term rate of reaction in words by referring to the graph. (2)

3.2 At which time, 10 s or 30 s, does the decomposition take place at a higher rate? Refer to the graph to give a reason for the answer. (2)

3.3 Write down the initial concentration of **P**(g). (1)

3.4 The decomposition is carried out in a $2\,dm^3$ container. Calculate the average rate $(in\,mol.s^{-1})$ at which **P**(g) is decomposed in the first 10s. (6)

3.5 Draw a potential energy diagram for the reaction. Clearly indicate the following on the diagram:

- Positions of the reactants and products
- Activation energy (E_a) for the forward reaction (3)

3.6 An increase in temperature will increase the rate of decomposition of P(g). Explain this statement in terms of the collision theory. (2)

4. A group of learners uses the reaction of EXCESS hydrochloric acid (HCl) with zinc (Zn) to investigate factors which influence reaction rate. The balanced equation for the reaction is:

$$Zn(s) + 2HCl(aq) \longrightarrow ZnCl_2(aq) + H_2(g)$$

They use the same volume of hydrochloric acid and 1,2 g of zinc in each of five experiments. The reaction conditions and temperature readings before and after completion of the reaction in each experiment are summarised in the table below.

Experiment	REACTION CONDITIONS				Time (s)
	Concentration of HCl (mol dm^{-3})	Temperature (°C)		State of division of the 1,2 g of Zn	
		Before	After		
1	0,5	20	34	granules	50
2	0,5	20	35	powder	10
3	0,8	20	36	powder	6
4	0,5	35	50	granules	8
5	0,5	20	34	granules	11

4.1 Is the reaction between hydrochloric acid and zinc EXOTHERMIC or ENDOTHERMIC? Give a reason for the answer by referring to the data in the table. (2)

4.2 Give a reason for the difference in reaction rate observed for Experiments 1 and 2. (1)

4.3 The learners compare the results of Experiments 1 and 3 to draw a conclusion regarding the effect of concentration on reaction rate. Explain why this is not a fair comparison. (3)

4.4 How does the rate of the reaction in Experiment 5 compare to that in Experiment 1? Write down FASTER THAN, SLOWER THAN or EQUAL TO.

Write down the factor responsible for the difference in the rate of reaction and fully explain, by referring to the collision theory, how this factor affects reaction rate. (5)

4.5 Calculate the rate at which the hydrochloric acid reacts in Experiment 4 in $mol.s^{-1}$. (6)

TOPIC 7: Rate and Extent of Reaction

GRADE 12: CONSOLIDATION QUESTIONS TOTAL: 53 MARKS

MULTIPLE CHOICE

1. Which one of the following statements about heat of reaction (ΔH) of a system is **incorrect**?

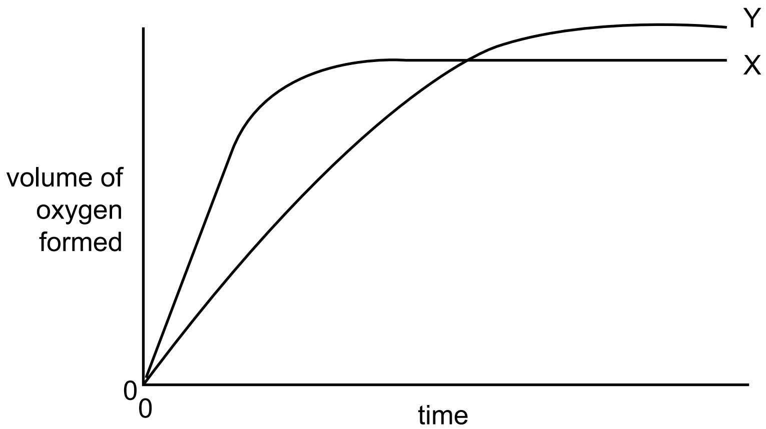
   A The heat of reaction is the average kinetic energy of the system.

   B The heat of reaction is the energy of the products minus the energy of the reactants.

   C The heat of energy can be positive or negative.

   D The heat of reaction is the net change of chemical potential energy of the system (2)

2. In the diagram, curve X was obtained by observing the decomposition of $100\,cm^3$ of $1,0\,mol.dm^{-3}$ hydrogen peroxide, H_2O_2, catalysed by manganese (IV) oxide. The products of this reaction are water and oxygen.



   Which alteration of the original experimental conditions would produce curve Y?

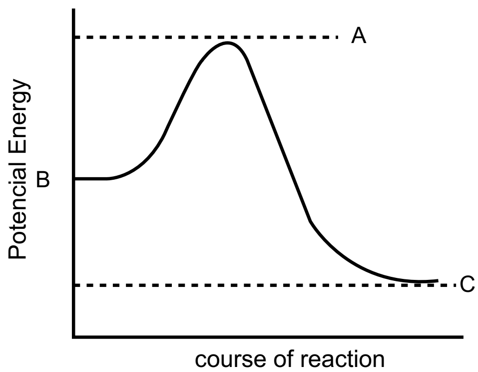
   A Adding water.

   B Adding $0,1\,mol.dm^{-3}$ hydrogen peroxide.

   C Using less manganese (IV) oxide.

   D Lowering the temperature. (2)

3. Consider the following energy profile graph. Potential energy values A, B and C are indicated on the graph. The change in enthalpy for the forward reaction is given by:



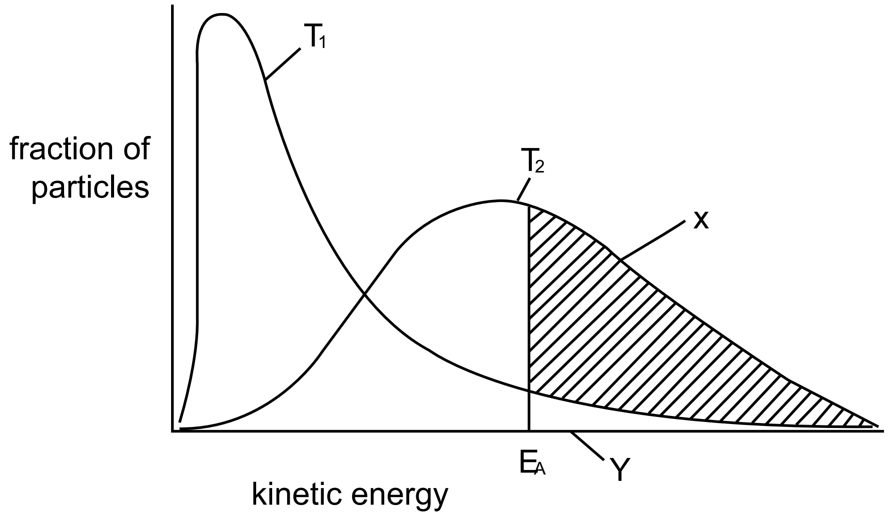
   A A-C

   B B+C

   C B-C

   D A-B (2)

4. The graph below represents the fraction of particles against the kinetic energy for an identical sample of reacting particles at two different temperatures, T_1 and T_2.



Which of the following statements is true of the reacting particles and the graph above?

A $T_1 > T_2$ with area Y representing the fraction of particles having insufficient energy to react.

B $T_2 > T_1$ with area X representing the fraction of particles having sufficient energy to react.

C $T_2 > T_1$ with area X representing the amount of product at temperature T_2.

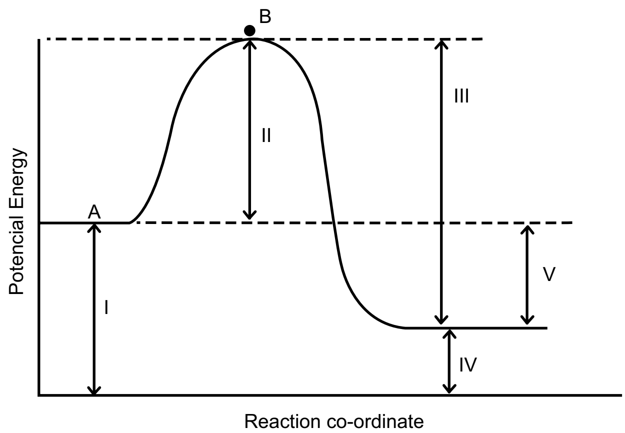
D $T_1 > T_2$ with area Y representing the amount of product at temperature T_1. (2)

LONG QUESTIONS

1. In order to investigate the rate of the reaction between a carbonate and an acid, calcium carbonate and excess of $2\,mol.dm^{-3}$ hydrochloric acid react in a reaction vessel. The balanced chemical equation for this reaction is

$$CaCO_3(s) + 2HCl(aq) \longrightarrow CaCl_2(aq) + CO_2(g) + H_2O(l)$$

Consider the potential energy profile for this reaction as illustrated below:



1.1 The graph has been labelled I – V to represent the various energies that are illustrated by this energy profile. Identify each of these energies on the profile. (5)

1.2 Using the molecular collision theory, explain why the chemical reaction must gain potential energy between position A and position B according to the energy profile. (2)

1.3 Provide a name for the position on the graph labelled B and what significant process takes place at this point. (2)

1.4 Name the type of reaction this graph represents. Explain how you came to this conclusion. (3)

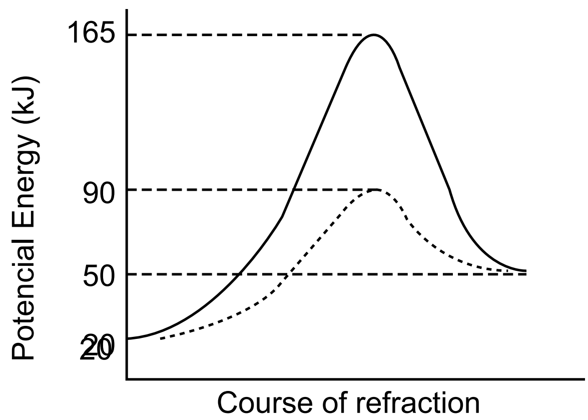
1.5 The same reaction takes place in the presence of a catalyst.
On the potential energy profile provided, show how the graph would change in the presence of a catalyst. (2)

1.6 How would the presence of a catalyst affect the value of the energy labelled V? Explain you answer. (3)

2. Consider the hypothetical reaction represented by the following, balanced chemical equation:

$$A_2(g) + 2B_2(g) \longrightarrow 2AB_2(g)$$

The potential energy profile graph for the above reaction is given below. The dash-dot line (–·–·–··) shows the effect of a catalyst on this reaction.



2.1 Define/explain the following terms:

a) Heat of reaction. (2)

b) Activated complex. (2)

2.2 Is the forward reaction exothermic or endothermic? (1)

2.3 Write down the numerical value (measured in kJ) for the:

a) Energy of the reactants in the forward uncatalysed reaction. (1)

b) Activation energy for the forward uncatalysed reaction. (2)

c) Energy of the activated complex in the forward uncatalysed reaction. (1)

d) Heat of reaction (ΔH) for the forward uncatalysed reaction. (2)

e) Activation energy for the forward catalysed reaction. (1)

f) Activation energy for the forward catalysed reaction. (2)

3. A series of experiments are conducted to investigate the effect of different factors on the rates of a chemical reaction between sulphuric acid and zinc. The balanced chemical equation for the reaction is:

$$Zn(s) + H_2SO_4(aq) \longrightarrow ZnSO_4(aq) + H_2(g)$$

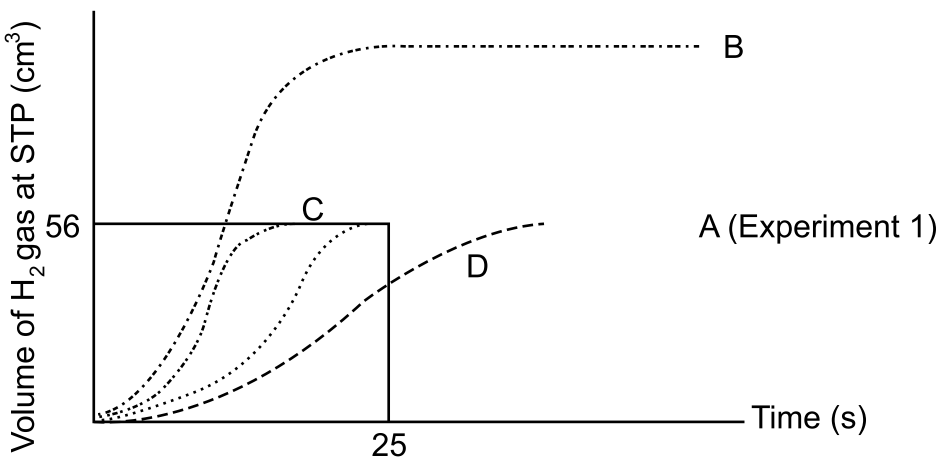
FOUR different experiments are conducted using the conditions given in the table below:

Experiment	Temperature (°C)	Concentraion of H_2SO_4 (mol dm^{-3})	State of zinc
1	25	0,05	Powder
2	25	0,05	Granules
3	35	0,05	Powder
4	25	0,10	Powder

In each of the four experiments the same volume of sulphuric acid and the same mass of zinc is used. The **zinc is always in excess** and is fully covered by the sulphuric acid.

The rate of reaction for each experiment is monitored by measuring the volume of hydrogen gas produced at STP against time. The results of the four experiments are shown in the graph below.

Graph A corresponds to EXPERIMENT 1.



3.1 Explain why graph **A** levels out after t = 25 s. (2)

3.2. State which of the graphs **B**, **C** or **D** corresponds to: (1)

a) Experiment 2. (1)

b) Experiment 3. (1)

c) Experiment 4. (1)

3.3 With reference to reaction rate and the collision theory, explain the differences between graph **A** (Experiment 1) and graph **B**. (4)

3.4 Use information from graph A to calculate the average rate of the reaction in Experiment 1 over the first 25 s. Give your answer in units of moles of H_2 gas per second (mol.s^{-1}). (5)

GRADE 12: WORKSHEET MEMORANDUM

MULTIPLE CHOICE

1. D ✓✓ Reaction rates are always measured per unit time thus the measure of the change in concentration of reactants and produce over that amount of time (per unit time) correctly most correctly defines the rate of a chemical reaction. (2)

2. B ✓✓ Catalysts provide an alternative energy pathway to a reaction by lowering/ reducing the amount of activation energy needed for an effective/ successful collision. (2)

3. B ✓✓ In III, IV and V, the zinc metal is in a powder form hence greater surface area. Also., In III, the temperature of the reaction is very high at 70ºC while in IV, the concentration is very high at $0,5\,mol.dm^{-3}$. These factors will make rate of reactions the fastest. (2)

4. B ✓✓ Even though the surface area of the zinc has decreased, there is a much greater concentration of HCl in the reaction, thus it will be the increase in concentration of the HCl that will increase the rate of reaction. (2)

5. D ✓✓ From the position indicated by the activation energy on the x-axis, graph D shows the greatest area under the curve representing the most number of particles that will have the necessary energy for a successful/effective collision. (2)

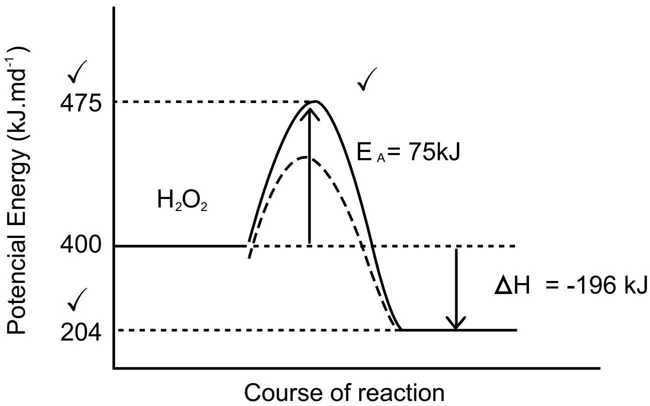
LONG QUESTIONS

1.1 Increase ✓ (1)

1.2 Increase ✓ (1)

1.3 The minimum energy required for a reaction to take place ✓ ✓ (2)

1.4



(3)

1.5 On graph above with the dashed (– – – –) curve ✓ ✓ (2)

1.6 Catalyst provides an alternative energy path thus lowering the amount of ✓ activation energy required for the reaction to proceed. More particles will have the minimum ✓ energy needed for effective collisions ✓ to occur per unit time, thus rate of reaction will increase. (3)

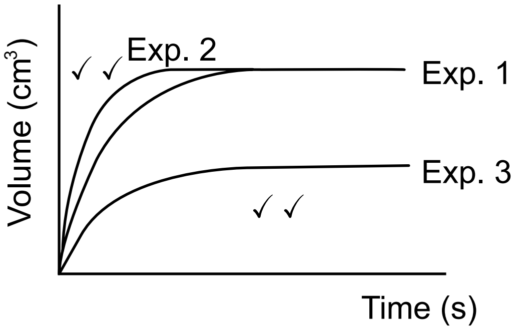
2.2.1 t_1 ✓ (1)

2.2.2 t_3 ✓ (1)

2.2 No more hydrogen gas is being produced as the acid has run out (zinc is in excess)✓✓ (2)

2.3 between t_1 and t_2 ✓✓ (2)

2.4



(4)

3.1 The rate of change of concentration of P ✓✓ (2)

3.2 10s . ✓ The gradient or steepness of the graph at t = 10s is greatest ✓ (2)

3.3 $0,27\,\text{mol.dm}^{-3}$ ✓ (1)

3.4 At t = 0s: $c = 0,27\,\text{mol.dm}^{-3}$

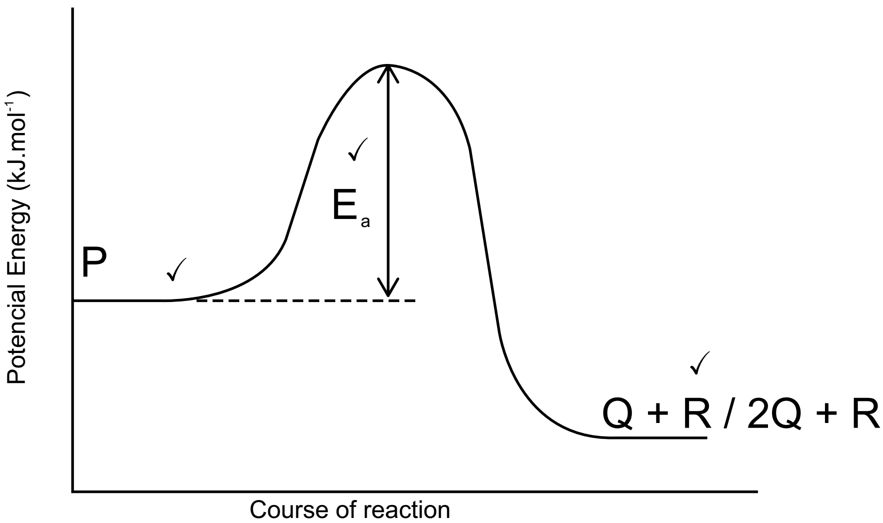
$n = c.V$✓ thus $n = 0,27 \times 2 = 0,54\,\text{mol}$ ✓

At t = 10s: $c = 0,15\,\text{mol.dm}^{-3}$

$n = c.V$ thus $n = 0,15 \times 2 = 0,30\,\text{mol.dm}^{-3}$ ✓

$\text{Rate} = \frac{\Delta n}{\Delta t} = \frac{0,30 - 0,54✓}{10 - 0✓} = -0,024\,\text{mol.s}^{-1}$ ✓ (6)

3.5



(3)

3.6 More heat energy in the system thus particles have greater kinetic energy. ✓

Thus, greater number of successful/effective collisions per unit time. ✓ (2)

4.1 Exothermic ✓ The temperature increases during the reaction. ✓ (2)

4.2 The surface area in experiment 2 compared to experiment 1, is larger. ✓ (1)

4.3 There are two changes to reaction condition between the two experiments. ✓ There is an increase in concentration between 1 and 3 ✓ as well as a change in surface area of the zinc metal from granules to powder ✓ (3)

4.4 Faster than. ✓ As all other conditions are the same, there must have been the addition of a catalyst to the reaction. ✓ The catalyst will provide an alternative energy pathway for the reaction by lowering the activation energy ✓ .. There will be more reactant particles with kinetic energy equal to or greater than the activation energy. ✓ Thus there will be more effective collisions per unit time. ✓ (5)

4.5 $n = \frac{m}{M} = \frac{12}{65✓} = 0,018\,\text{mol}$ ✓

Thus, total number of moles of Zn reacted $= 2 \times 0,018 = 0,037\,\text{mol}$ ✓

$\text{Rate} = \frac{\Delta n}{\Delta t} = \frac{0 - 0,037✓}{8✓} = -4,63 \times 10^{-3}\,\text{mol.s}^{-1}$ ✓ (6)

TOPIC 7: Rate and Extent of Reaction

GRADE 12: CONSOLIDATION QUESTIONS MEMORANDUM TOTAL: 53 MARKS

MULTIPLE CHOICE

1. A ✓✓ (2)
2. B ✓✓ (2)
3. C ✓✓ (2)
4. D ✓✓ (2)

LONG QUESTIONS

1.1 I — Energy of reactants ✓

II — Activation energy ✓

III — Energy of product formation ✓

IV — Energy of products ✓

V — Heat of reaction (enthalpy) ✓ (5)

1.2 Particles must have enough energy to have a successful collision. ✓
There must be enough energy to allow for successful orbital overlap to occur. ✓ (2)

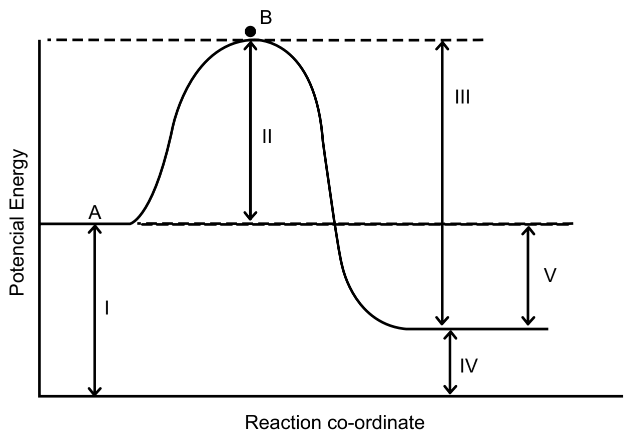
1.3 Activated complex ✓ — This is where the old bonds of the reactants break and the new bonds of the product form. This is where the reaction begins. ✓ (2)

1.4 Exothermic ✓ - the energy of the products after the reaction is less ✓ than the energy of the reactants before the reaction. ✓

OR

More energy is released on product formation ✓ than energy needed for activation. ✓ (3)

1.5



(2)

1.6 There will be no change. ✓ catalysts only lowers the energy of activation ✓ and does not affect the energy of the products at the end of the reaction ✓. This means that the heat of reaction will not be affected. (3)

2.1 a) The amount of energy that is added or removed from a chemical reaction ✓✓ (2)

b) The minimum amount of energy required for a reaction to take place. ✓✓ (2)

2.2 Endothermic reaction. ✓ (1)

2.3 a) 20kJ ✓ (1)

b) 145kJ ✓✓ (2)

c) 165kJ ✓ (1)

d) 30kJ ✓ (2)

e) 90kJ ✓ (1)

f) 70kJ ✓✓ (2)

3.1 The acid (H_2SO_4) has run out ✓ as zinc is in excess thus there no hydrogen gas is produced. ✓ (2)

3.2 a) D ✓ (1)

b) C ✓ (1)

c) B ✓ (1)

3.3 The concentration of H_2SO_4 in experiment 4 has increased thus there will be more acid particles per unit volume present ✓. This means that there will be a higher collision frequency ✓ increasing the changes of more effective collisions per unit time ✓. This will lead to a faster rate of reaction compared to Experiment 1 (Graph A) as well as more hydrogen gas produced per unit time. ✓ (4)

3.4

$$\text{Average Rate} = \frac{\text{number of moles of } H_2 \text{ gas formed}}{\Delta t} \quad ✓$$

$$n = \frac{v}{V_m} = \frac{56}{22,4} = 2,5 \text{ mols of } H_2 \text{ produced} \quad ✓✓$$

$$\text{Average rate} = \frac{2,5}{25} \quad ✓$$

$$\text{Average rate} = 0,1 \text{mol.s}^{-1} \quad ✓$$

(5)

TOPIC 8: Chemical equilibrium

GRADE 12: WORKSHEET

MULTIPLE CHOICE

1. Methanol, CH_3OH, can be produced by the following:

$$CO(g) + 2H_2(g) \rightleftharpoons CH_3O(g) \qquad \Delta H < 0$$

The conditions necessary to maximize the equilibrium yield of CH_3OH are

A low temperature and low pressure

B high temperature and low pressure

C low temperature and high pressure

D high temperature and high pressure (2)

2. Consider the reaction taking place in a closed container:

$$A(g) + 2B(g) \rightleftharpoons AB_2(g) \quad \Delta H < 0$$

The addition of a suitable catalyst would:

A Speed up the reverse reaction only.

B Decrease the rate of the reverse reaction.

C Result in a higher yield of product.

D Allow equilibrium to be reached in a shorter time period. (2)

3. The expression for the equilibrium constant (K_c) of a hypothetical reaction is given as follows:

$$K_c = \frac{[D]^2.[C]}{[A]^3}$$

Which one of the following equations for a reaction at equilibrium matches the above expression?

A $3A(s) \rightleftharpoons C(g) + 2D(g)$

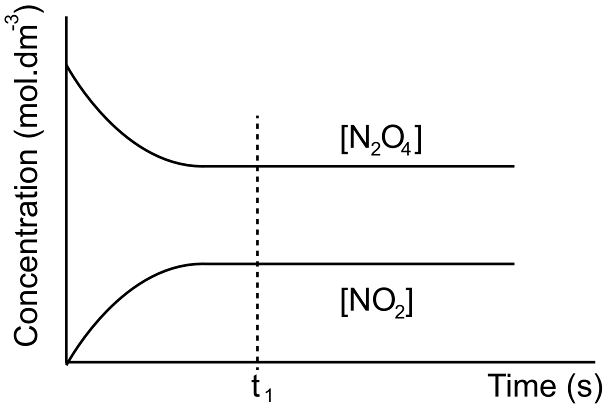
B $3A(l) \rightleftharpoons C(aq) + 2D(aq)$

C $3A(aq) + B(s) \rightleftharpoons C(g) + D_2(g)$

D $3A(aq) + B(s) \rightleftharpoons C(aq) + 2D(aq)$ (2)

4. The graph below represents the decomposition of $N_2O_4(g)$ in a closed container according to the following equation:

$$N_2O_4(g) \rightleftharpoons 2NO_2(g)$$



Which one of the following correctly describes the situation at t_1?

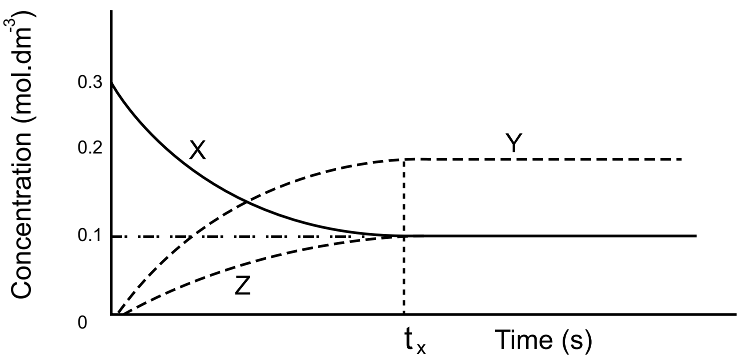
A The N_2O_4 gas is used up.

B The NO_2 gas is used up.

C The rate of the forward reaction equals the rate of the reverse reaction.

D The concentrations of the reactant and product are equal. (2)

5. A gas X is placed in a sealed container at t = 0 s. The gas decomposes into gases Y and Z. A chemical equilibrium between the three gases is reached at $t = t_x$. The following graph of concentration versus time shows the changes that occurred during the reaction:



The equation for the reaction is:

A $3X \rightleftharpoons 2Y + Z$

B $X \rightleftharpoons Y + Z$

C $X \rightleftharpoons 2Y + Z$

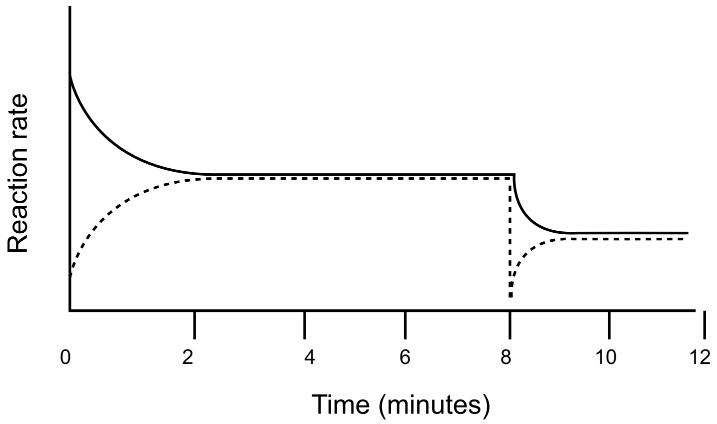
D $2X \rightleftharpoons 2Y + Z$ (2)

LONG QUESTIONS

1. The gas XA_3 is introduced into an empty flask which is then sealed. The XA_3 gas decomposes and sets up equilibrium at $300\,^{\circ}C$, as represented by the following balanced chemical equation.

$$2\,XA_3(g) \rightleftharpoons 2\,XA_2(g) + A_2(g)$$

The graph below shows the change in reaction rate over 12 minutes:



1.1 Write down the balanced equation which is represented by the **broken line**. (2)

1.2 After 8 minutes the pressure is decreased.

1.2.1 State *Le Chatelier's Principle*. (2)

1.2.2 Apply *Le Chatelier's principle* to the reaction in order to EXPLAIN the changes shown on the graph between 8 and 10 minutes. (3)

1.3 Write down an expression for the equilibrium constant (K_c) for this reaction. (2)

1.4 Initially 5mol of $XA_3(g)$ was sealed in a $2\,dm^3$ flask. At equilibrium the reaction mixture contained exactly 1,5mol of $A_2(g)$ at $300°C$. Calculate the value of the equilibrium constant (K_c) at this temperature. (6)

2. 7 moles of nitrogen gas (N_2) and 2 moles of oxygen gas (O_2) are placed in an empty container of volume $2\,dm^3$. The container is sealed and the following equilibrium is established:

$$N_2(g) + O_2(g) \rightleftharpoons 2NO(g)$$

The K_c value for this reaction at $25\,°C$ is $4,8 \times 10^{-31}$.

2.1 What information does this value of K_c indicate with regards to the amount of NO(g) in the equilibrium mixture at $25\,°C$? (2)

The container is heated and the system reaches a new equilibrium at $2\,500\,°C$. At this temperature it is found that there are 0,4 moles of NO(g) present.

2.2 How much N_2 reacted? (1)

2.3 How much O_2 is there at equilibrium? (1)

2.4 Determine the concentration of NO at equilibrium. (3)

2.5 Determine the K_c value at this temperature. (4)

2.6 Making use of *Le Chatelier's principle*, explain why the forward reaction is endothermic. (4)

3. A certain amount of NO_2 gas is sealed in a gas syringe at $25\,°C$. When equilibrium is reached, the volume occupied by the reaction mixture in the gas syringe is $80\,cm^3$. The balanced chemical equation for the reaction taking place is:

$$2NO_2(g) \rightleftharpoons N_2O_4(g) \qquad \Delta H < 0$$

dark brown colourless

3.1 State two conditions necessary for chemical equilibrium to occur. (2)

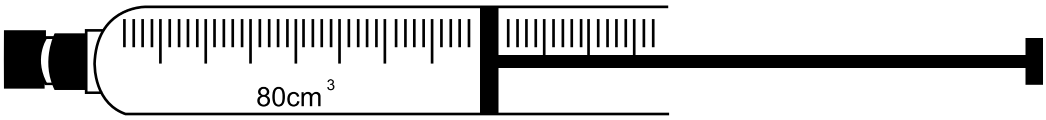
3.2 At equilibrium the concentration of the $NO_2(g)$ is $0,2\,mol.dm^{-3}$. The equilibrium constant for the reaction is 171 at $25\,^oC$.

3.2.1 Write an expression for the equilibrium constant, K_c, of this reaction. (2)

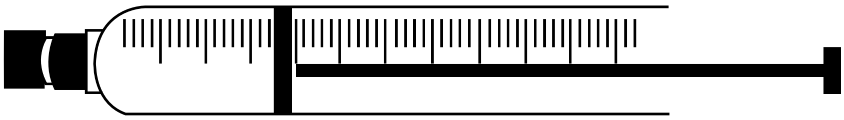
3.2.2 Calculate the number of moles of N_2O_4 at equilibrium. (3)

3.2.3 Calculate the initial number of moles of $NO_2(g)$ placed in the gas syringe. (3)

3.3 The diagram below shows the reaction mixture in the gas syringe after equilibrium is established as seen at time t_1.



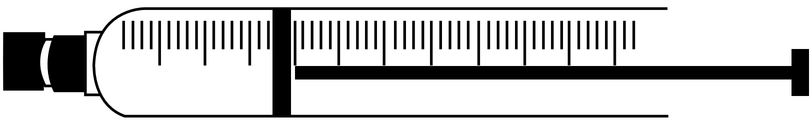
The pressure is now increased by decreasing the volume of the gas syringe at constant temperature as illustrated in the diagram belo



Immediately after increasing the pressure, before the new equilibrium is established, the colour of the reaction mixture in the gas syringe appears darker than before.

3.3.1 Give a reason for this observation. (1)

After a while, at time t_2, a new equilibrium is established as illustrated below. The colour of the reaction mixture in the gas syringe now appears lighter than the initial colour.



3.3.2 Use *Le Chatelier's principle* to explain the colour change observed in the gas syringe. (4)

3.4 The temperature of the reaction mixture in the gas syringe is now increased and, at time t_3, a new equilibrium is established. State **and** explain how each of the following will be affected?

3.4.1 Colour of the reaction mixture (3)

3.4.2 Value of the equilibrium constant, K_c (3)

4. A chemical engineer studies the reaction of nitrogen and oxygen in a laboratory. The reaction reaches equilibrium in a closed container at a certain temperature, T, according to the following balanced equation:

$$N_2(g) + O_2(g) \rightleftharpoons 2NO(g)$$

Initially, 2 mol of nitrogen and 2 mol of oxygen are mixed in a $5\,dm^3$ sealed container.
The equilibrium constant (K_c) for the reaction at this temperature is $1,2 \times 10^{-4}$.

4.1 Is the yield of NO(g) at temperature T HIGH or LOW? Give a reason for the answer. (2)

4.2 Calculate the equilibrium concentration of NO(g) at this temperature. (8)

4.3 How will each of the following changes affect the YIELD of NO(g)?
Write down only INCREASES, DECREASES or REMAINS THE SAME.

4.3.1 The volume of the reaction vessel is decreased at constant temperature. (1)

4.3.2 An inert gas such as argon is added to the mixture. (1)

4.4 It is found that K_c of the reaction increases with an increase in temperature.
Is this reaction exothermic or endothermic? Explain the answer. (3)

TOPIC 8: Chemical equilibrium

GRADE 12: CONSOLIDATION QUESTIONS TOTAL: 81 MARKS

MULTIPLE CHOICE

1. Ethene, C_2H_4, can be produced in the following industrial system:

   $C_2H_6(g) \rightleftharpoons C_2H_4(g) + H_2(g)$ $\Delta H > 0$

   The conditions that are necessary to maximise the equilibrium yield of C_2H_4 are:

   A low temperature and low pressure.

   B low temperature and high pressure.

   C high temperature and low pressure.

   D high temperature and high pressure. (2)

2. One of the stages in the industrial preparation of iron from its ore is represented by the equation below:

   $$Fe_2O_3(s) + 3CO(g) \rightleftharpoons 2Fe(l) + 3CO_2(g) \qquad \Delta H < 0$$

   The following possible disturbances can be made to the equilibrium system:

   (i) Pressure may be increased.

   (ii) CO_2 may be removed.

   (iii) Temperature may be increased

   Which of the changes mentioned above will favour the forward reaction?

   A (i), (ii) and (iii)

   B (i) and (ii) only

   C (ii) only

   D (iii) only (2)

3. Consider the following equilibrium:

   $$H_2(g) + I_2(g) \rightleftharpoons HI(g)$$

   The volume of the equilibrium system is increased and a new equilibrium is established. Compared to the rates of the reactions in the original equilibrium, which of the following describes the rates of the forward and reverse reactions, as well as the K_c in the new equilibrium?

A	increased	increased	unchanged
B	decreased	decreased	unchanged
C	decreased	increased	increases
D	unchanged	unchanged	decreases

(2)

LONG QUESTIONS

1. Sulfuric acid is made using the industrial process known as the Contact process at $430\,°C$. This process allows sulfur dioxide to react with oxygen forming sulfur trioxide according to the equilibrium reaction shown below:

$$2SO_2(g) + O_2(g) \rightleftharpoons 2SO_3(g) \qquad \Delta H = -192 kJ.$$

The Contact process gets its name due the contact that the reactant molecules make with the surface of a catalyst that is added at the start of the reaction.

1.1 Define the term 'catalyst' (2)

1.2 Define the term 'dynamic chemical equilibrium'. (2)

1.3 By writing down only the words INCREASE, DECREASE or STAYS THE SAME, state the effect the following changes will have on the amount of SO_2 produced when the system is at equilibrium:

a) SO_3 is removed from the reaction vessel. (1)

b) The temperature of the system is decreased. (1)

c) The pressure in the system is decreased. (1)

d) More catalyst is added to the system. (1)

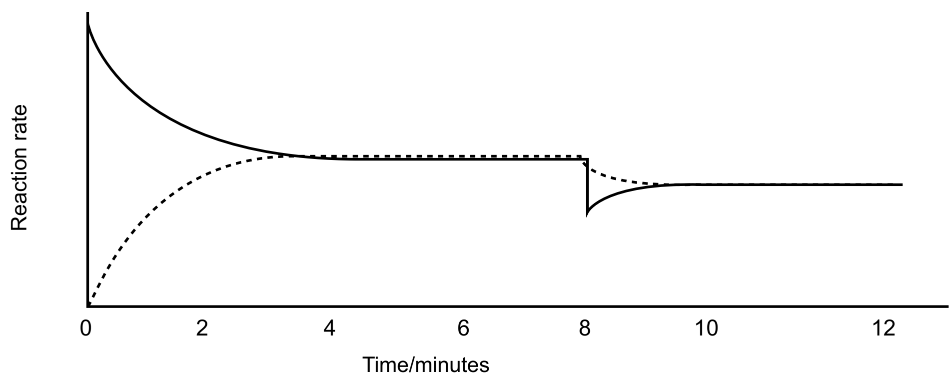
1.4 When equilibrium is reached at $430\,°C$, it was found that 0,2 mol of SO_2, 0,4 mol of O_2 and 0,2 mol SO_3 were formed in a $2\,dm^3$ container. Calculate the equilibrium constant for this reaction at this temperature. (4)

1.5 By considering the reaction, the best conditions to produce high yields of SO_3 are at low temperatures and high pressures.

a) Explain why will these conditions are considered to be ideal? (4)

b) Practically, the reaction takes place at the relatively high temperature of $430\,°C$ and a relatively low pressure of 2 atmospheres. Explain why these less than ideal conditions are actually used in industry. (4)

1.6 Consider the graph shown below which illustrates how the rate of formation of SO_3 changes with time in the Contact process.



This graph shows the changes in reaction rates for a period of 14 minutes.

a) What do the solid and broken lies represent on this graph? (2)

b) Why do these lines have the curved shapes as seen on the graph? (2)

c) When does the reaction reach equilibrium for the first time? (1)

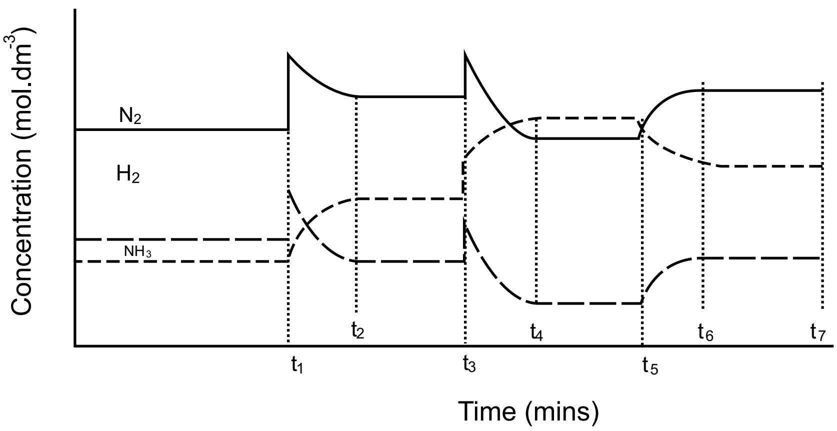
d) Explain what has happened to the reaction between t = 8 and t = 12 minutes. (4)

e) How will the equilibrium constant, K_c be affected by this disturbance? Use INCREASE, DECREASE or STAYS THE SAME. (2)

2. A fertiliser company produces ammonia on a large scale at a temperature of 450 ºC. The balanced equation below represents the reaction that takes place in a sealed $2\,dm^3$ container.

$$N_2(g) + 3H_2(g) \rightleftharpoons 2NH_3(g) \qquad \Delta H < 0$$

To meet an increased demand for fertiliser, the management of the company instructs their engineers to make the necessary adjustments to the dynamic chemical equilibrium of the reaction to increase the yield of ammonia. In a trial run on a small scale in the laboratory, the engineer makes adjustments to the equilibrium mixture. The graphs below represent the results obtained.



2.1 Explain what is meant by the term – dynamic chemical equilibrium? (2)

2.2 During which time intervals would the reaction have been in dynamic chemical equilibrium? (2)

2.3 Using *le Chatelier's Principle*, <u>identify</u> and <u>explain</u> the changes made to the equilibrium mixture between each of the following times:

2.3.1 t_1 and t_2 (3)

2.3.2 t_5 and t_6 (3)

2.4 At t_3, both the reactants and product showed a sudden increase in concentration.

2.4.1 What do you think happened at this point to cause the increase in concentration? (2)

2.4.2 Using *le Chatelier's Principle*, explain how the equilibrium now re-establishes itself between t_3 and t_4. (3)

2.5 At t_7, the following amounts of reactant and product were present at equilibrium at a temperature of 450 ºC:

- 1,28mol of H_2,
- 49,6g of N_2
- $12,31\,dm^3$ of NH_3 gas at STP

The volume of the reaction container is $2\,dm^3$

2.5.1 Write down an expression for the equilibrium constant (K_c) for this reaction. (2)

2.5.2 Calculate the value of K_c for this reaction at 450 °C (5)

2.5.3 What does the magnitude of K_c indicate about the equilibrium position of the reaction? (2)

2.5.4 What would happen to the value of the equilibrium constant (K_c) calculated above, under the following conditions? Simply answer INCREASE, DECREASE or STAY THE SAME)

(a) N_2 (g) is removed from the system

(b) The temperature is decreased to 350 °C

(c) The size of the reaction vessel is increased (3)

3. A hypothetical reaction is represented by the balanced equation below:

$$A(g) + 2B(g) \rightleftharpoons 2C(g)$$

Initially 3 moles of A(g) and 6 moles of B(g) are mixed in a 5 dm^3 sealed container. When the reaction reaches equilibrium at 25 °C, it is found that 4 moles of B(g) is present.

3.1 Define the term chemical equilibrium. (2)

3.2 Show by calculation that the equilibrium concentration of C(g) is 0,4 $mol.dm^{-3}$. (3)

3.3 How will an increase in pressure, by decreasing the volume of the container, influence the amount of C(g) in the container at 25 °C?
Write down INCREASES, DECREASES or REMAINS THE SAME. Explain the answer. (3)

3.4 The initial number of moles of B(g) is now increased while the initial number of moles of A(g) remains constant at 25 °C. Calculate the number of moles of B(g) that must be ADDED to the original amount (6 mol) so that the concentration of C(g) is 0,8 $mol.dm^{-3}$ at equilibrium. The equilibrium constant (K_c) for this reaction at 25 °C is 0,625. (9)

TOPIC 8: Chemical equilibrium

GRADE 12: WORKSHEET MEMORANDUM

MULTIPLE CHOICE

1. C ✓✓ Low temperatures will favoured the exothermic reaction which is the forward reaction producing more CH_3OH. High pressure will favour reaction producing fewer moles of gas, hence forward reaction. (2)

2. D ✓✓ Catalyst will increase the rate of both the forward and reverse/back reactions equally thus will allow the equilibrium to be reached in a much shorter time. (2)

3. D ✓✓ As K_c is the ratio of product of products to the product of the reactants, the concentration of products D and C will be the numerators raised to the power of their balancing numbers. A will thus be a denominator without B which is a solid and cannot be included in the K_c expression. (2)

4. C ✓✓ When both lines are horizontally parallel to each other, then a state of dynamic equilibrium exists between them. This means that the rate of the forward reaction will equal the rate of the reverse/back reaction. (2)

5. D ✓✓ The decrease in X and the increase in Y is the same, thus X and Y must have the same reaction ratio. Z is half that of Y and thus must have half the reaction ratio of Y. (2)

LONG QUESTIONS

1.1 A chemical substance that is added to a reaction to lower the activation energy of the system causing it to proceed faster ✓ without itself undergoing any chemical or physical change. (2)

1.2 This is when the rate of the forward reaction ✓ is equal ✓ to the rate of the reverse reaction in a closed/isolated chemical system. ✓ (3)

1.3 a) DECREASE ✓ (1)

b) DECREASE ✓ (1)

c) INCREASE ✓ (1)

d) NO CHANGE ✓ (1)

1.4

$$c = \frac{n}{V}$$

$$[SO_2] = \frac{0,2}{2} = 0,1 mol.dm^{-3}$$

$$[O_2] = \frac{0,4}{2} = 0,2 mol.dm^{-3}$$

$$[SO_3] = \frac{0,2}{2} 0,1 mol.dm^{-3}$$

$$K_a = \frac{[SO_3]^2}{[SO_2]^2.[O_2]}$$

$$= \frac{(0,1)^2}{(0,1)^2.(0,2)}$$

$$K_a = 5$$

(_)

1.5 a) Under both these conditions, the forward reaction will be favoured ✓ ✓ which allows for maximum amount of SO_3 to be produced. ✓ ✓ (4)

b) If the temperature is too low, the rate of reaction becomes too slow and this will not be profitable as it would take too long to produce sufficient quantities of SO_3. ✓ ✓

If pressure is too high, it is very expensive to construct equipment that can withstand the very high pressure. This means reaction is done at lower pressures to keep costs down. ✓ ✓ (4)

1.6 a) Solid line = rate of forward reaction ✓
Broken line = rate of reverse/back reation. ✓ (2)

b) They represent changes in rates of these reactions. ✓ ✓ (2)

c) At approximately t = 4s ✓ (1)

d) There has been a decrease in pressure ✓. Both reaction rates decrease initially however the forward decrease the most ✓ as the back/reverse reaction rate is favoured ✓ to increase the pressure in the system. ✓ (4)

e) STAYS THE SAME ✓ ✓ (2)

2.1 Small thus low concentration of product;
Equilibrium lies to the left ✓ thus very little NO produced ✓ (2)

	N_2	O_2	2NO
Ratio	1	1	2
Initial	7mol	2mol	0
Change	-0,2mol	-0,2mol	+0,4mol
Equilibrium	6,8mol	1,8mol	0,4mol

2.2 0,2mol ✓ (1)

2.3 1,8mol (1)

2.4
$$c = \frac{n}{V}$$
$$= \frac{0,4}{2} \quad ✓ ✓$$
$$c = 0,2\,mol.dm^{-3} \quad ✓$$ (3)

2.5
$$K_c = \frac{[NO]^2}{[N_2][O_2]}$$
$$= \frac{(0,2)^2}{(3,4)(0,9)} \quad ✓ ✓$$
$$K_c = 0,013 \quad ✓$$ (4)

2.6 K_c has increased at higher temperatures ✓ thus indicating that there are more products at this temperature ✓ According to *le Chatelier's Principle*, this means that the equilibrium has moved to right favouring the forward reaction ✓ tp absorb the excess energy. Thus the forward reaction must be endothermic to absorb the increase in heat energy ✓ (4)

3.1 The system must be closed and a reversible reaction must exist. ✓
The rate of the forward reaction equals the rate of the reverse reaction. ✓ (2)

3.2.1 $K_c = \frac{[N_2O_4]}{[NO_2]^2}$ ✓ ✓ ✓ (2)

3.2.2 $[N_2O_4] = K_c.[NO_2]^2$

$[N_2O_4] = 171 \times (0,2)^2$

$= 6,84\,mol.dm^{-3}$ ✓

and $n = c.V$ ✓

$= (6,84)(0,08)$

= 0,55mol ✓ (3)

3.2.3

Ratio	2	1
Initial	1.116mol	0
Change	-1,10mol	+0,55mol
Equilibrium	0,016mol	0,55
[Equilibrium]		

- n = cV
  = (0,2) .(0,08)
  $= 0,016\,mol\,of\,NO_2$ ✓
- Now 0,55mol of N_2O_4 was produced at equilibrium, therefore 1,10mol of NO_2 was used ($NO_2 : N_2O_4 = 2:1$ ✓
- Thus initial amount of NO_2 present = 0,016 + 1,10 = 1,116 ✓ (3)

3.3.1 The molecules are closer to one another thus intensifying the colour for a brief time. ✓ (1)

3.3.2 According to *le Chatelier's Principle*, an increase in pressure favours the reaction that leads to smaller number of moles (volume) of gas ✓ which will be the forward reaction ✓. This forms N_2O_4 ✓ which is colourless, leading to paler colour ✓ (4)

3.4.1 Darker ✓
Increase in temperature favours endothermic ✓ reaction, forming brown gas ✓ (3)

3.4.2 K_c will decrease ✓ as increase in T will decrease yield ✓ ✓ (3)

4.1 LOW ✓
There is a small K_c value which is less than 1 ✓ (2)

4.2

	N_2	O_2	NO
Ratio **(R)**	1	1	2
Initial **(I)**	2	2	0
Change **(C)**	X	X	2X
Equilibrium **(E)**	2 – X ✓	2 X ✓	2X ✓
Equilibrium concentration	$\frac{2-X}{5}$	$\frac{2-X}{5}$	$\frac{2X}{5}$

Let the amount of N_2 that is used up be X mol

Therefore the amount of O_2 used = X mol, thus amount of NO formed = 2X mol

Thus the amount present at equilibrium: N_2 = 2 – X mol

O_2 = 2 – X mol

NO = 2X mol

$K_c = \frac{[NO]^2}{[N_2][O_2]}$ ✓

$1{,}2 \times 10^{-4} = \frac{\frac{(2X)^2}{5}}{\frac{(2-X)}{5} \cdot \frac{(2-x)}{5}}$ ✓

X = 0.0109mol ✓

Thus $[NO] = \frac{2x0.0109}{5}$ ✓

$= 4{,}36 \times 10^{-3}$ mol.dm^{-3} ✓ (8)

7.3.1 Remains the same ✓ (1)

7.3.2 Remains the same ✓ (1)

7.4 Endothermic ✓

An increase in the K_c value shows that the forward reaction is favoured as the products will increase. ✓

This favours the removal of heat energy thus the forward reaction must be endothermic. ✓ (3)

GRADE 12: CONSOLIDATION QUESTIONS MEMORANDUM TOTAL: 81 MARKS

MULTIPLE CHOICE

1. C ✓✓ The forward reaction is endothermic, the high temperature will favour the reaction to reduce heat energy, thus endothermic reaction. Low pressure will favour the reaction that produces the most number of moles of substance to increase the pressure, thus forward reaction (2)

2. C ✓✓ Only the removal of CO_2 will favour the forward reaction as an increasing both pressure and temperature will favour the reverse/back reaction (2)

3. B ✓✓ As the volume is increased, the pressure of the system decreases. However, as there are 2mols of reactant and product, neither one reaction will be favoured over the other, however, with a volume increase, the collision frequency will decrease so both reactions will decrease in rate overall. The K_c value will not change as pressure does not affect K_c (2)

LONG QUESTIONS

1.1 A substance that will increase the rate of a chemical reaction by lowering the activation energy ✓ of the system but does not undergo a chemical change itself. ✓ (2)

1.2 A reversible chemical reaction where the rate of the forward reaction is equal ✓ to the rate of the reverse/back reaction. ✓ (2)

1.3 a) Decrease ✓ (1)

b) Decrease ✓ (1)

c) Increase ✓ (1)

d) Stay the same ✓ (1)

1.4 $K_c = \frac{[SO_3]^3}{[SO_2]^2[O_2]}$ ✓ $[SO_2]$: $c = \frac{n}{V} = \frac{0,2}{2} = 0,1 \text{mol.dm}^{-3}$

$= \frac{(0,1)^3}{(0,1)^2(0,2)}$ ✓✓ $[O_2]$: $c = \frac{n}{V} = \frac{0,4}{2} = 0,2 \text{mol.dm}^{-3}$

$K_c = 0,5$ at 430°C ✓ $[SO_3]$: $c = \frac{n}{V} = \frac{0,2}{2} = 0,1 \text{mol.dm}^{-3}$ (4)

1.5 a) Low temperatures will favour the exothermic reaction to counteract the change which is the forward reaction to produce more SO_3. ✓✓
High pressure will favour the reaction with the fewest moles which is the forward reaction to produce more SO_3. ✓✓ (4)

b) If temperatures are too low, the rate of reaction is too slow and it takes far too long to produce the SO_3 from the reaction. Thus, a higher temperature is used to keep the reaction rates at a reasonable level. ✓✓
If temperatures are too high, it is too costly to build equipment for the reaction, so a lower pressure is used to keep costs of production lower. ✓✓ (4)

1.6 a) Solid = rate of forward reaction ✓
Broken = rate of reverse/back reaction ✓ (2)

b) They represent the rates either slowing down as in the case of the forward reaction ✓ or speeding up as in the case of the reverse reaction. ✓ (2)

c) At 4 minutes ✓ (1)

d) The rates of both forward reactions decrease, thus there has been a decrease in pressure.✓ ✓ This will mean that the reverse reaction will not decrease as much as it will be favoured ✓ to produce more moles of gas to counteract the change.✓ (4)

e) Stay the same. ✓ ✓ (2)

2.1 The rate of forward and reverse reactions are equal ✓ in a closed/isolated system. ✓ (2)

2.2 $t_0 - t_1$; $t_2 - t_3$; $t_4 - t_5$; $t_6 - t_7$ ✓ ✓ (–1 for any incorrect) (2)

2.3.1 The concentration of nitrogen is increased. OR more nitrogen was added. ✓ Forward reaction favoured • using H_2 and forming more NH_3. ✓ (3)

2.3.2 The temperature is increased. ✓ Reverse reaction (endothermic) favoured ✓ using NH_3 and forming more H_2 and N_2. ✓ (3)

2.4.1 Decrease in volume of reaction vessel. ✓ ✓ (2)

2.4.2 Pressure increase ✓ thus according to *le Chatelier's Principle*, system favours the formation of the side that produces with fewer moles of gas to counteract the change. ✓ Forward reaction favoured. ✓ (3)

2.5.1 $K_c = \frac{[NH_3]^2 ✓}{[N_2][H_2]^3 ✓}$ (2)

2.5.2 $[H_2]$: $c = \frac{n}{V} = \frac{1,28}{2} = 0,64\ mol.dm^3$ ✓

$[N_2]$: $n = \frac{m}{M} = \frac{49,6}{28} = 1,77\ mol$

$c = \frac{n}{V} = \frac{1,77}{2} = 0,89\ mol.dm^3$ ✓

$[NH_3]$: $n = \frac{V}{Vm} = \frac{12,31}{22,4} = 0,55 mol$

$c = \frac{n}{V} = \frac{0.55}{2} = 0,23\ mol.dm^3$ ✓

$K_c = \frac{[NH_3]^2}{[N_2][H_2]^3}$

$= \frac{(0,23)^2}{(0,89)(0,64)^3}$ ✓

= 0,23 ✓ (5)

2.5.3 Small K_c value – low yield OR Equilibrium lies to the left OR high concentration of reactants. ✓ ✓ (2)

2.5.4 a) stays the same ✓

b) Increases ✓

c) stays the same ✓ (3)

3.1 The stage in a chemical reaction when the rate of the forward reaction equals the rate of the reverse reaction. ✓ ✓ (2)

3.2 If there were initially 6mols of B present, and at equilibrium there are 4 moles of B left, then 2 moles of B have reacted. ✓

The reaction ratio of B : C is 2 : 2, which is 1 : 1

Then 2moles of C has formed. ✓

$c = \frac{n}{V}$

$c = \frac{2}{5}$

$c = 0,4 mol.dm^{-3}$ ✓ (3)

3.3 Increases ✓

Increase in pressure will favour reaction which has fewer moles of gas. ✓

This means that the forward reaction will be favoured. ✓ (3)

3.4

	A	B	C
Ratio **(R)**	1	2	2
Initial **(I)**	3	x	0
Change **(C)**	-2	-4	+4
Equilibrium **(E)**	1 ✓	x - 4 ✓	4 ✓
	$c = \frac{n}{V}$ $c = \frac{1}{5}$ $c = 0,2 mol.dm^{-3}$ ✓	$c = \frac{n}{V}$ $c = x - \frac{4}{5} mol.dm^{-3}$	$c = \frac{n}{V}$ $n = c.V$ $n = 0,8 \times 5$ n=4mol

$K_c = \frac{[C]^2}{[A][B]^2}$ ✓

$0,625 = \frac{(0.8)^2}{(0,2)(x - \frac{4}{5})^2}$ ✓ ✓

x = 15,3 mol

Thus n(B) = 15,3 – 6 ✓

= 9,3 mol ✓

Initially 6mols of B were in container, thus amount of B added must difference between total number of moles of B present at start and the initial amount present. (9)

TOPIC 9: Acids and Bases

GRADE 12: WORKSHEET

MULTIPLE CHOICE

1.1 Lowry-Bronsted acid is defined as a substance that:

A is sour

B is a proton donor

C neutralises a base

D has a pH of less than 7 (2)

1.2 Which one of the acids listed below is an example of a polyprotic acid?

A HNO_3

B HCl

C H_2SO_4

D CH_3COOH (2)

1.3 The acid ionisation constants for two acids, and the concentrations of solutions containing these acids, are given below:

Acid	K_a	Concentration
HF	$6,6 \times 10^{-4}$	$1mol.dm^{-3}$
HI	$3,2 \times 10^{9}$	$1mol.dm^{-3}$

Which of the following statements is true?

A The HI solution will be a better electrical conductor than the HF solution.

B HF is a stronger acid than HI.

C The two solutions contain the same concentrations of H3O+ ions.

D Neither solution will conduct electricity because HF and HI are covalently bonded. (2)

1.4 A pupil performing a titration consulted the following table of available indicators:

bromothylmol blue	6,0 – 7,6
phenolphthalein	8,4 – 10,0
methyl orange	3,1 – 4,4

The pupil decided the indicator she should use would be methyl orange. The two species she was titrating against each other were:

A ethanoic acid and sodium carbonate

B ethanoic acid and sodium hydroxide

C nitric acid and sodium hydroxide

D nitric acid and sodium carbonate (2)

1.5 The pH of an aqueous solution of HCl is 3. How will adding distilled water to the HCl solution affect the ionization constant of water (K_w) and the OH^- concentration?

	K_W	$[OH^-]$
A	Increase	Increase
B	Decrease	Decrease
C	Remain the same	Increase
D	Remain the same	Decrease

(2)

LONG QUESTIONS

1. Sulfur dioxide gas, amongst other gases, is released as a pollutant when coal, a fossil fuel, is burned in a power station. This gas is highly soluble and will dissolve easily in atmospheric water to form sulfurous acid, a form of acid rain. The acid ionises in water according to the following equation:

$$H_2SO_3(g) + H_2O(l) \longrightarrow H_3O^+(aq) + HSO_3^-(aq)$$

1.1. Define an acid according to the Lowry-Bronsted model. (1)

1.2. Name the H_3O^+ cation produced by this ionisation reaction. (1)

1.3. Identify the solute and solvent in the above reaction. (2)

A student collects some rain water after a heavy storm. He wants to determine the concentration of the sulfurous acid in the rain water. To do this he decides to titrate the rain water against a standard solution of potassium hydroxide.

1.4. Write a balanced chemical equation for the reaction between sulfurous acid and potassium hydroxide. (4)

1.5. The following table lists the indicators that are most commonly used in a titration.

Indicator	pH Range
Phenolphthalein	8.2 - 10
Bromothymol Blue	6.0 – 7.6
Methyl Orange	3.2 – 4.4

1.5.1. Which indicators would be most suitable to find the equivalence point when sulfurous acid reacts with potassium hydroxide in a titration? (1)

1.5.2. Hydrolysis of a salt is where a salt reacts with water and water decomposes. The following balanced chemical equation shows the hydrolysis of water.

$$H_2O(l) \longrightarrow H^+(aq) + OH^-(aq)$$

a) Write the dissociation of the salt produced in the titration of sulfurous acid and potassium hydroxide. (2)

b) Use your knowledge of hydrolysis; explain your answer to 1.5.1. (4)

1.6. Bromocresol green is another suitable indicator for this reaction. Bromocresol green is a weak acid which ionizes according to the following balanced chemical equation where HIn represents the indicator in the equation.

$$HIn(aq) + H_2O(l) \rightleftharpoons In^-(aq) + H_3O^+(aq)$$

(yellow) (blue)

Using *Le Chatelier's Principle*, explain why bromocresol green displays a blue colour in a basic solution. (4)

1.7. What is a *standard solution*? (1)

1.8. Calculate the mass of potassium hydroxide which must be used to make $300\,cm^3$ of a $0,1 mol.dm^{-3}$ solution. (4)

1.9. Calculate the hydronium ion concentration in the $0,1 mol.dm^{-3}$ KOH solution and state how this relates to the pH of the solution. (4)

1.10. It was found that $15\,cm^3$ of potassium hydroxide neutralises 0,375 litres of sulfurous acid. Calculate the concentration of the sulfurous acid. (4)

1.11. Scientists will often wash down the sides of the conical flask with distilled water when performing a titration. This additional water does not affect the equivalence point.

1.11.1. What is the reason for 'washing down' the sides of the conical flask? (1)

1.11.2. Why would the equivalence point not affected by the addition of water? (1)

1.12. You are given a sulphuric acid solution and a sulphurous acid solution, both with a concentration of 2 M.

1.12.1. Why would sulphurous acid have a lower K_a value? Explain fully. (2)

1.12.2. Why would sulphuric acid have a better electrical conductivity? Explain fully. (2)

TOPIC 9: Acids and Bases

GRADE 12: CONSOLIDATION QUESTIONS TOTAL: 68 MARKS

MULTIPLE CHOICE

1.1 A base is defined as:

A a proton donor

B an electron donor

C a proton acceptor

D an electron acceptor (2)

1.2 Which ONE of the following is a CORRECT description for a $0,1 mol.dm^{-3}$ sulphuric acid solution?

A Dilute strong acid

B Dilute weak acid

C Concentrated weak acid

D Concentrated strong acid (2)

1.3 Which one of the following salts will decrease the pH of a sample of distilled water when dissolved in the water?

A NaCl

B K_2SO_3

C Li_2CO_3

D NH_4Cl (2)

1.4 Which one of the following indicators is most suitable for use in the titration of sodium hydroxide with ethanoic acid?

A	Cresol Blue	1,2 – 1,8
B	Methyl Orange	3,1 – 4,4
C	Bromothymol Blue	6,0 – 7,6
D	Phenolphthalein	8,4 – 10,0

(2)

LONG QUESTIONS

1. Phosphoric acid (H_3PO_4) is a weak, polyprotic acid.

1.1 Define an acid. (2)

1.2 Define a ***weak*** acid? (2)

1.3 Give a reason why phosphoric acid is referred to as a ***polyprotic*** acid. (1)

2. A student needs to determine the concentration of a phosphoric acid solution. She decides to titrate the phosphoric acid against a standard potassium hydroxide solution. The balanced chemical equation is given below:

$$H_3PO_4(aq) + 3KOH(aq) \longrightarrow K_3PO_4(aq) + 3H_2O(l)$$

2.1 What is meant by a "standard solution"? (2)

2.2 Calculate the mass of KOH needed to make up $300\,cm^3$ of a $0,2\,mol.dm^{-3}$ KOH solution. (4)

2.3 Which one of the indicators listed below should be used in this titration? Briefly explain your answer.

Methyl orange	3,1 – 4,4
Bromothymol blue	6,0 – 7,6
phenolphthalein	8,4 – 10,0

(3)

2.4 During the titration she found that $15\,cm^3$ of the $0,2\,mol.dm^{-3}$ KOH solution neutralises $20\,cm^3$ of the phosphoric acid solution. Calculate the concentration of the phosphoric acid solution. (4)

3.1 What is meant by "hydrolysis of a salt"? (2)

3.2 Explain how the hydrolysis of NH_4NO_3 in water results in the aqueous solution of this salt **not** being neutral. Include one or more equations with your answer. (4)

4. Anhydrous oxalic acid is an example of an acid that can donate two protons and thus ionises in two steps as represented by the equations below:

I: $(COOH)_2(aq) + H_2O(l) \rightleftharpoons H_3O^+(aq) + H(COO)_2^-(aq)$

II: $H(COO)_2^-(aq) + H_2O(l) \rightleftharpoons H_3O^+(aq) + (COO)_2^{2-}(aq)$

4.1 Write down ONE word for the underlined phrase in the above sentence. (1)

4.2 Write down the FORMULA of each of the TWO bases in reaction II. (2)

4.3 Write down the FORMULA of the substance that acts as the *ampholyte* in reactions I and II. Give a reason for the answer. (2)

4.4 A standard solution of $(COOH)_2$ of concentration $0,20\,mol.dm^{-3}$ is prepared by dissolving a certain amount of $(COOH)_2$ in water in a $250\,cm^3$ volumetric flask. Calculate the mass of $(COOH)_2$ needed to prepare the standard solution. (4)

5. The acid ionisation constant K_a for the ionisation of each of the hypothetical acids H_2X, HY and HZ in water at $25\,°C$ is given in the table below.

Acid	K_a
H_2X	$2,8 \times 10^{-3}$
HY	$1,2 \times 10^{6}$
HZ	6×10^{-4}

5.1 State the difference between a strong acid and a weak acid. Give one example of each. (Choose from H_2X, HY or HZ.) (4)

5.2 Which acid, H_2X, HY or HZ, has the lowest pH in water? Justify your choice. Assume that the concentration of each acid is the same. (3)

5.3 Which acid, H_2X, HY or HZ, is the weakest electrical conductor in water? Justify your choice. Assume that the concentration of each acid is the same. (3)

5.4 The equation for the ionisation of H_2X in an aqueous solution is:

$$H_2X(aq) \rightleftharpoons 2H^+(aq) + X^-(aq)$$

The concentration of unionised H_2X in a solution at $25\,^{o}C$ is $0,2\,mol.dm^{-3}$.

5.4.1 Write an expression for K_a for H_2X (2)

5.4.2 Calculate the concentration of X^- ions in the solution. (4)

5.5 $25,0\,cm^3$ of acid HZ is neutralised in a titration by $32,4\,cm^3$ of $0,1 mol.dm^{-3}$ NaOH solution. An aqueous solution of the salt NaZ is produced in the reaction.

5.5.1 Write down a balanced chemical equation for the reaction of HZ with NaOH. (The phase of each substance is not required.) (2)

5.5.2 Calculate the concentration of acid HZ. (4)

5.6 Consider the equations given below for the dissociation of NaZ in water and for the ionisation of water.

$$NaZ(s) \rightleftharpoons Na^+(aq) + Z^-(aq)$$

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

Consider the interaction between the ions in the aqueous solution of the salt NaZ and hence predict whether the solution would have a pH of LESS THAN 7, EQUAL TO 7, OR GREATER THAN 7. Using hydrolysis. explain your answer fully. (5)

GRADE 12: WORKSHEET MEMORANDUM

MULTIPLE CHOICE

1.1 B ✓✓ As per the textbook definition for a Lowry-Bronsted acid (2)

1.2 C ✓✓ Polyprotic acids carry more than one acidic hydrogen in their structure. H_2SO_4 has two acidic protons in its structure thus is classified as diprotic which is an example of a polyprotic acid. (2)

1.3 A ✓✓ HI has a very high K_a value compared to HF which is very small. This indicates that HI is a strong acid which will then ionise.

completely to release a large amount of ions into solution, hence a high conductivity. (2)

1.4 D ✓✓ Methyl orange indicates in the acidic region, thus the salt form from the acid-base reaction would have to be from a strong acid and a weak base. Nitric acid is a strong acid and sodium carbonate is a weak base (2)

1.5 C ✓✓ The ionisation constant for water will always remain the same at a particular temperature, however by adding water, this will increase the [OH^-] due to the weak ionisation of water that takes place which adds both H_3O^+ and OH^- ions into solution (2)

LONG QUESTIONS

1.1 An acid is a proton donor. ✓ (1)

1.2 Hydronium ion ✓ (1)

1.3 Solute: Sulfurous acid ✓
Solvent: Water ✓ (2)

1.4 $H_2SO_3(aq) + 2KOH(aq) \longrightarrow K_2SO_3(aq) + H_2O(l)$ ✓✓✓ (4)

1.5.1 Phenolphthalein ✓ (1)

1.5.2 a) $K_2SO_3(s) \rightleftharpoons 2K^+(aq) + SO_3^{2-}(aq)$ ✓✓(each product) (2)

1.5.2 b) K_2SO_3 is the salt of the strong base KOH and weak acid H2SO3.
This means that the conjugate base of the weak acid, SO32 will hydrolyse with water ✓ according to the following equation:

$$SO_3^{2-} + H_2O \longrightarrow HSO_3^- + OH^- \quad ✓$$

This releases extra OH ions into solution ✓ which will then make the solution basic, ✓ hence K2SO3 is a basic salt and phenolphthalein will indicate in this region. (4)

1.6 A base increases [OH^-] which reacts with [H_3O^+] ✓ causing the [H_3O^+] to decrease ✓
According to *le Chatelier's Principle*, the reaction which increases [H_3O^+] will be thus be favoured ✓
Forward reaction favour resulting in a blue colour ✓ (4)

1.7 A solution of known concentration ✓ (1)

1.8 $c = \frac{n}{v}$ $n = \frac{m}{M}$

$n = c.V$ $m = n.V$

$n = 0,1 \times 0,3$ $m = 0,03✓ \times 56✓$

$n = 0,03mol✓$ $m = 1,68g✓$ (4)

1.9 $K^+ + OH^- \rightleftharpoons KOH$

$K_w = [OH^-][H_3O^+] = 1 \times 10^{-14}✓$

$[OH^-] = 0,1mol.dm^{-3}$ ✓

$[H_3O^+] = \frac{1 \times 10^{-14}}{0,1} = 1 \times 10^{-13}mol.dm^{-3}$ ✓

pH is a measure of hydronium ions✓ (4)

1.10 $\frac{caVa}{cbVb} = \frac{na}{nb}$

$ca = \frac{na.cb.Vb}{nb.Va}$ ✓

$= \frac{1 \times 0,1 \times 0,015}{2 \times 0,375}$ ✓ ✓

$ca = 0,002\,mol.dm^{-3}$ ✓ (4)

1.11.1 To ensure all solution added has mixed and to get an accurate result. ✓ (1)

1.11.2 The number of moles in solution remains the same. ✓ (1)

1.12.1 Sulfurous acid is weak ✓ and ionises partially. ✓ (2)

1.12.2 Sulfuric acid as it is strong and ionises almost completely ✓
thus there are more ions in the solution the better the conductivity ✓ (2)

GRADE 12: CONSOLIDATION QUESTIONS MEMORANDUM — TOTAL: 68 MARKS

MULTIPLE CHOICE

1.1 C ✓✓ The standard definition of a Lowry-Bronsted bases as per the textbook. (2)

1.2 A ✓✓ Sulfuric acid is a strong acid. The concentration of $0,1 mol.dm^{-3}$ is a very low concentration, thus will indicate that it has a large amount of water present in the solution, hence is a dilute acid. (2)

1.3 D ✓✓ NH_4Cl is the salt of the strong acid HCl which is almost fully ionised and the weak base NH_4OH with is only partially dissociated $\therefore$ there will be an excess of H_3O^+ ions in an aqueous solution of NH_4Cl $\therefore$ pH<7. (2)

1.4 D ✓✓ The salt formed will be sodium ethanoate which comes from the strong base and weak acid. Thus, hydrolysis will occur in the solution to produce excess OH^- ions. This will give a basic solution which is then indicted by phenolphthalein. (2)

LONG QUESTIONS

1.1 A proton donor ✓✓ (2)

1.2 A weak acid ionises ✓ only partially ✓ in water (2)

1.3 It can donates more than one proton ✓ (1)

2.1 A solution of known concentration ✓ (2)

2.2 $n = c.V = (0,2).(0.3✓) = 0,06 mol✓$ (4)

$m = n.M = (0,06).(56✓) = 3,36 g✓$

2.3 Phenolpthalein ✓

H_3PO_4 is a weak acid ✓, KOH is a strong base ✓ thus will form a basic salt (3)

2.4 $H_3PO_4(aq) + 3KOH(aq) \longrightarrow K_3PO_4(aq) + 3H_2O(l)$

$$\frac{c_aV_a}{c_bV_b} = \frac{n_a}{n_b}$$

$$c_a = \frac{n_a.c_b.V_b}{n_b.V_a} \quad ✓$$

$$= \frac{1 \times 0,2 \times 0.015}{3 \times 0,020} \quad ✓✓$$

$$c_a = 0,05 mol.dm^{-3} \quad ✓$$ (4)

3.1 This is the ability of ions to react with water molecules ✓, thus altering the pH of the solution. ✓ (2)

3.2 $NH_4NO_3(s) \longrightarrow NH_4^+(aq) + NO_3^-(aq)$

NH_4^+ ion will react with water molecules ✓

$NH_4^+ + H_2O \longrightarrow NH_{3+}H3O^+$ ✓

$[H_3O^+]$ increases ✓, pH decreases ✓ (4)

4.1 Diprotic ✓ (1)

4.2 H_2O ✓ $(COO)_2^{2-}$ ✓ (2)

4.3 $H(COO)_2^-$ ✓

In reaction 1 it is acting as a base, and in reaction 2 it is acting as an acid. ✓ (2)

4.4 $c = \frac{n}{v}$ $n = \frac{m}{M}$

$n = c.V$ $m = n.M$

$= 0,2 \times 0.25$ ✓ $= 0,05 \times 90$ ✓

$n = 0.05 \, mol$ ✓ $m = 4,5 g$ ✓ (4)

5.1 A strong acid ionises almost completely ✓ in an aqueous solution, whereas a weak acid only ionises partially ✓

strong – HY ✓

weak = HZ / H_2X ✓ (4)

5.2 HY ✓ the lowest pH means the highest $[H_3O]^+$ ✓. As HY has a very high K_a, it means it ionises (to form H_3O^+ ions) almost completely ✓ ∴ high $[H3O]+$. (3)

5.3 HZ ✓ – Very low K_a value, which means it has not ionised much, ✓ ∴ not many free ions to carry a current ✓ (3)

5.4.1 $K_a = \frac{[H^+]^2[X^-]}{H_2X}$ ✓ ✓ (2)

5.4.2

$$K_a = \frac{[H^+]^2[X^-]}{H_2X}$$

$$K_a.[H_2X] = [H^+]^2.[X^-]$$

$$2,8 \times 10^{-3} \times 0,2 = [H^+]^2.[X^-]$$

$$[H^+]^2.[X^-] = 5,6 \times 10^{-4}$$

$$[X^-] = \sqrt[3]{5,6 \times 10^{-4}}$$

$$[X^-] = 0,082 \, mol.dm^{-3}$$

(_)

5.5.1 $HZ + NaOH \longrightarrow NaZ$✓ $+ H_2O$ ✓ (2)

5.5.2

$$\frac{c_a V_a}{c_b V_b} = \frac{n_a}{n_b}$$ ✓

$$\frac{c_a.25}{01, \times 32,4} = \frac{1}{1}$$ ✓

$$Ca = \frac{0,1 \times 32,4}{25}$$ ✓

$$= 0,13 \, mol.dm^{-3}$$ ✓

(4)

5.6 NaZ is a salt that comes from the weak acid HZ and strong base NaOH ✓

$$NaZ \longrightarrow Na^{+}(aq) + Z^{-}(aq)$$

Z^{-} is a strong conjugate base from the weak acid HZ, thus Z^{-} will react with water ✓ to undergo hydrolysis according to the following reaction:

$Z^{-} + H_2O \longrightarrow HZ + OH^{-}$ ✓

This will produce excess OH^{-} ions ✓ hence the solution will be basic

(pH GREATER THAN 7) ✓ (5)