1 Why are chemical equilibria referred to as "dynamic"?

2 The effect upon the rate f many reactions of an increase in temperature of 10°C is to double the reaction rate. Explain this effect in terms of the collision theory.

3 Distinguish between "position" of an equilibrium and " rate of attainment" of an equilibrium.

4 Account for the increase in reaction rate brought about by contact catalysts. eg Platinum gauze in Hydrogen / Oxygen reaction.

5 Explain the fact that a catalyst is often used in an equilibrium reaction, even though, the reverse reaction is also accelerated by the catalyst.

6 For each of the equilibrium systems represented below predict the effect of

a) increasing the pressure on the position of the equilibrium,
b) increasing the concentration of the substance underlined on each of the species present.

i) $\underline{N_2(g)} + 3H_2(g) \rightleftharpoons 2NH_3(g)$
ii) $CH_4(g) + Cl_2(g) \rightleftharpoons CH_3Cl(g) + \underline{HCl(g)}$
iii) $N_2(g) + O_2(g) \rightleftharpoons 2NO(g)$
iv) $\underline{2SO_2(g)} + O_2(g) \rightleftharpoons 2SO_3(g)$
v) $2H_2(g) + \underline{O_2(g)} \rightleftharpoons 2H_2O(g)$
vi) $H_2(g) + CO_2(g) \rightleftharpoons \underline{CO(g)} + 2H_2O(g)$
vii) $NH_4Cl(s) \rightleftharpoons NH_3(g) + \underline{HCl(g)}$
viii) $BaSO_3(g) \rightleftharpoons BaO(s) + SO_2(g)$
ix) $2Pb(NO_3)_2(s) \rightleftharpoons 2PbO(s) + \underline{4NO_2(g)} + O_2(g)$
x) $\underline{4NH_3(g)} + 5O_2(g) \rightleftharpoons 4NO(g) + 6H_2O(g)$

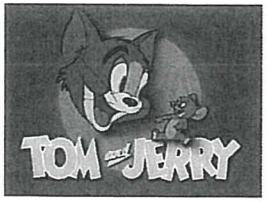
7 How will an increase in temperature affect each of the following equilibria?

i) $N_2(g) + 3H_2(g) \rightleftharpoons 2NH_3(g) + heat$
ii) $H_2O(l) + heat \rightleftharpoons 2H_2O(g)$
iii) $N_2(g) + O_2(g) \rightleftharpoons 2NO(g) \quad \Delta H = +$
iv) $2O_3(g) \rightleftharpoons 3O_2(g) \quad \Delta H = -$
v) $CaCO_3(s) + 172kJ \rightleftharpoons CaO(s) + CO_2(g)$

8 For the reaction

$$2CO(g) + O_2(g) \rightleftharpoons 2CO_2(g) + 564\ kJ$$

Predict and explain the effect that
a) lowering the pressure,
b) lowering the temperature
will have on the position of the equilibrium.



9 For the reaction in the Contact Process

$$SO_2(g) + O_2(g) \rightleftharpoons 2SO_3(g) \quad \Delta H = -196\ kJ$$

What would be the best conditions to produce the greatest yield of $SO_3(g)$?

10 Given the following equilibrium,

$$H_2O(g) + C(s) \rightleftharpoons CO(g) + H_2(g) \quad \Delta H = +396\ kJ$$

What are four ways in which the forward reaction may be driven further to completion?

11 Suppose that equilibrium has been attained in the following reaction.

$$4HCl(g) + O_2(g) \rightleftharpoons 2Cl_2(g) + 2H_2O(g) + 108\ kJ$$

State in which direction (toward reactants or products) the equilibrium will be shifted by each of the following changes
a) introduce some more HCl(g),
b) removal of the water vapour,
c) cooling the reaction vessel,
d) adding some Helium gas,
e) reducing the volume of the reaction vessel.

12 The reaction between H_2 and I_2 to form HI is exothermic and reversible.
a) Does the forward or reverse reaction have the greater energy?
b) Will the forward or reverse reaction be increased more by raising the temperature? Explain.

13 Suppose that equilibrium has been attained in the following reaction.

$$3Fe(s) + 4H_2O(g) \rightleftharpoons Fe_3O_4(s) + 4H_2(g)$$

State in which direction (toward reactants or products) the equilibrium will be shifted by each of the following changes
a) introduce some more Fe(s),
b) removal of the water vapour,
c) reducing the volume of the reaction vessel.

14 The following reaction takes place in one step.

$$X_2(g) + 2Y(s) \rightleftharpoons 2XY(s) \quad \Delta H = -120\ kJ$$

Activation energy of forward reaction is 90 kJ

a) Draw a graphical representation of the energies involved in this equilibrium.
b) Show and explain what effect a catalyst will have on these energies.
c) Draw a diagram to show how the rates of the forward and reverse reactions change until equilibrium is achieved.

15 Explain each of the following.
a) A sample of a finely divided metal catalyst is more effective than an equal weight of the metal in the form of a single cube.
b) Your body converts sugar and oxygen to carbon dioxide and water at 37°C but it takes considerable heat to burn the same quantity of sugar in air.
c) Very sensitive colour films are often stored in refrigerators to extend their short shelf life.

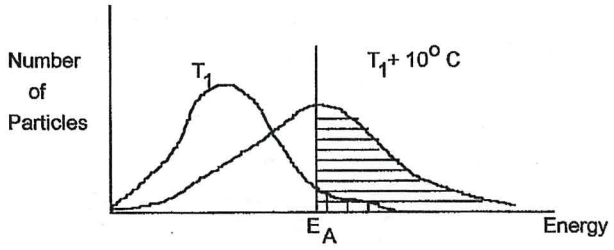
Chemistry 12 Assignment Answer Key

CHEMICAL EQUILIBRIUM

1 Dynamic equilibrium is when reaction is still occurring even though macroscopic properties are constant.

(1 mark)

2 In the collision theory a successful collision results in a reaction (rearrangement of pareticles) if the energy of collision excedds the activation energy (E_A) and the geometry is appropriate. The diagram shows the energy distribution fro a collection of particles at T_1 and T_1+10°C.



The diagonally shaded portion therefore shows the number of particlesw exceeding the E_A at T_1. The vertically shaded portion is the extra number exceeding the E_A at T_1+10°C. If these portions are equal in area the number of particles exceeding the activation energy would double. This would result in doubling of the reaction rate.

(3 marks)

3 Position of equilibrium: relative proportions of reactants and products
[products] > [reactants] equilibrium to right
[reactants] > [products] equilibrium to left
Rate of attainment: how fast the position of equilibrium is reached.

(2 marks)

4 A contact catalyst causes a particle to bond to its surface in such a way that the particle can react more easily

eg H - H
_____ Pt H H
molecule separates into free atoms on surface

Thus the reaction has an alternative pathway of lower activation energy. This would enable the reaction to proceed at a faster rate. The catalyst is regenerated in the reaction mechanism.

(1 mark)

5 A catalyst results in an equilibrium being established more quickly than without a catalyst. This tends to favour the desired reaction as product can be removed more quickly.

(1 mark)

6

	Increased Pressure	Increased amount of substance increases	decreases
i	favour products ie NH_3 side	$[N_2]$, $[NH_3]$	$[H_2]$
ii	no change to equilibrium	$[CH_4]$, $[Cl_2]$, $[HCl]$	$[CH_3Cl]$
iii	no change to equilibrium	$[N_2]$, $[O_2]$, $[NO]$	
iv	favour products ie SO_3 side	$[SO_2]$, $[SO_3]$	$[O_2]$
v	favour products ie H_2O side	$[O_2]$, $[H_2O]$	$[H_2]$
vi	favour reactants	$[H_2]$, $[CO_2]$, $[CO]$	$[H_2O]$
vii	favour reactants ie NH_4Cl side	m(NH_4Cl), $[HCl]$	$[NH_3]$
viii	no change to equilibrium	increasing mass of existing solid will not alter equilibrium	
ix	favour reactants ie $Pb(NO_3)_2$ side	m($Pb(NO_3)_2$), $[NO_2]$	m(PbO), $[O_2]$
x	favour reactants ie NH_3 side	$[NH_3]$, $[NO]$, $[H_2O]$	$[H_2O]$

(10 marks)

7

	Reaction
	adding heat to increase temperature
i	favours N_2 and H_2 production (ie reactants)
ii	favours $H_2O(g)$ production (ie products)
iii	favours NO production (ie products)
iv	favours O_3 production (ie reactants)
v	favours CaO & CO_2 production (ie products)

(5 marks)

8

	Change	Prediction equilibrium position will move to produce	Explanation
a	lower pressure	more CO & O_2 , ie reactants	system tries to counter change by producing more gas particles.
b	lower temperature	more CO_2, ie products	systems moves to replace the heat being removed by cooling.

(4 marks)

9 Greatest yield of SO_2 from the reaction

would be achieved by
- highest pressure possible – increase kinetics ✓
- lowest temperature which still allows reasonable reaction rate ✓
- removal of product as soon after formation as possible. ✓

A catalyst hastens the rate of attainment of equilibrium. ✗

(3 marks)

10 For the equilibrium

$$H_2O(g) + C(s) \Leftrightarrow CO(g) + H_2(g)$$

more CO and H_2 could be produced by
- decreasing pressure
- raise temperature of system
- increase $[H_2O(g)]$
- remove one of products as formed.

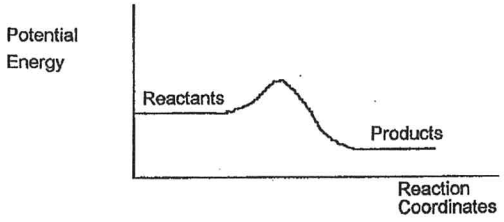
(4 marks)

11

	Change	Effect on equilibrium position
a	more HCl (g)	$[Cl_2]$ & $[H_2O]$ increases, ie shifts to right
b	remove H_2O (g)	$[Cl_2]$ increases, ie shifts to right
c	cooling	$[Cl2]$ & $[H_2O]$ increases, ie shifts to right
d	adding He (g)	no effect on equilibrium position
e	reduce volume	$[Cl_2]$ & $[H_2O]$ increases, ie shifts to right

(5 marks)

12 a The total energy of the system would be constant. Since reaction is exothermic, the potential energy of the reactants is greater than the potential energy of the products.



b Increasing the temperature favours the endothermic reaction as it absorbs the extra heat, ie the reverse reaction.

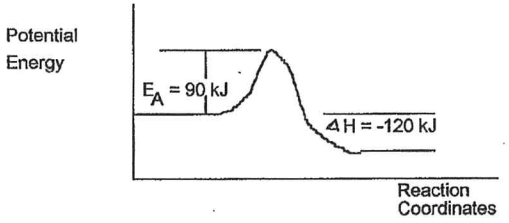
(2 marks)

13

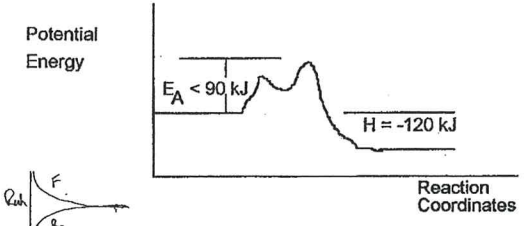
	Change	Effect on the equilibrium position
a	more Fe(s)	No effect
b	remove H_2O(g)	m(Fe) increases, ie shifts to left or ~~products~~ reactants
c	reduce volume	No effect as equal # of gas particles.

(3 marks)

14 a



b



(c) Rate F R Temp

(3 marks)

15 a greater surface area increases the number of possible collisions, thus the number of successful collisions (ie increases reaction rate)

b body contains enzymes (catalysts) which provide a much lower energy pathway for the combustion of sugar.

c lower temperatures decrease the number of reactant particles with energy > E_A ie lower reaction rate.

(3 marks)

term

50