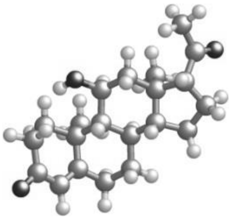

Chem!stry

Name: …………………… (   )

Class: ………………

Date: …… / …… / ……

Chemical Equilibrium – Worked Answers to Questions

Question One:

	$CH_3COOH_{(l)}$ +	$C_2H_5OH_{(l)}$ ⇌	$CH_3COOC_2H_{5(l)}$ +	$H_2O_{(l)}$
Initial amount / mol	1.00	4.00	0.00	0.00
Amount at equilibrium / mol	0.07	3.07	0.93	0.93

$$K_c = \frac{[\text{products}]}{[\text{reactants}]}$$

$$K_c = \frac{[CH_3COOC_2H_{5(l)}] \times [H_2O_{(l)}]}{[CH_3COOH_{(l)}] \times [C_2H_5OH_{(l)}]}$$

$$K_c = \frac{(0.93 \div V) \times (0.93 \div V)}{(0.07 \div V) \times (3.07 \div V)}$$

$$K_c = \frac{0.8649}{0.2149}$$

K_c = <u>4.02</u> (no units)

Question Two:

$$H_{2(g)} + I_{2(g)} \rightleftharpoons 2HI_{(g)}$$

	$H_{2(g)}$	$I_{2(g)}$	$2HI_{(g)}$	
Initial amount / mol	1.00	1.00	0.00	Total amount = 2.00 mol
Amount at equilibrium / mol	0.25	0.25	1.50	Total amount = 2.00 mol

$$K_p = \frac{\textit{partial pressure}\text{ products}}{\textit{partial pressure}\text{ reactants}}$$

$$K_p = \frac{P\ HI_{(g)}^2}{P\ H_{2(g)} \times P\ I_{2(g)}}$$

$$K_p = \frac{((1.5 \div 2.00) \times 1)^2}{((0.25 \div 2.00) \times 1) \times ((0.25 \div 2.00) \times 1)}$$

$$K_p = \frac{0.5625}{0.0156}$$

K_p = <u>36.0</u> (no units)

Question Three:

$$PCl_{5(g)} \rightleftharpoons PCl_{3(g)} + Cl_{2(g)}$$

	$PCl_{5(g)}$	$PCl_{3(g)}$	$Cl_{2(g)}$	
Initial amount / mol	1.00	0.00	0.00	Total amount = 1.00 mol
Amount at equilibrium / mol	0.61	0.39	0.39	Total amount = 1.39 mol

$$K_p = \frac{\textit{partial pressure}\text{ products}}{\textit{partial pressure}\text{ reactants}}$$

$$K_p = \frac{P\ PCl_{3(g)} \times P\ Cl_{2(g)}}{P\ PCl_{5(g)}}$$

$$K_p = \frac{((0.39 \div 1.39) \times 2) \times ((0.39 \div 1.39) \times 2)}{(0.61 \div 1.39) \times 2}$$

$$K_p = \frac{0.3149}{0.8777}$$

K_p = <u>0.360</u> atm

Question Four:

a) **i)** Shorter: the frequency of effective collisions increases with an increase in pressure.

ii) Reduced: by Le Chatelier's Theory, if the pressure of the system is increased, then the equilibrium position of the reaction will shift in the direction that opposes this change, *i.e.* in the direction that reduces the pressure. The reaction from right-to-left involves a decrease in the total number of moles of gas and therefore a decrease in pressure.

b)

$$K_p = \frac{P\ H_{2(g)} \times P\ CO_{(g)}}{P\ H_2O_{(g)}}$$

Note: The coke ($C_{(s)}$) is omitted from the expression for K_p because it is a solid.

c)

i)

$$H_2O_{(g)} + C_{(s)} \rightleftharpoons H_{2(g)} + CO_{(g)}$$

	$H_2O_{(g)}$	$C_{(s)}$	$H_{2(g)}$	$CO_{(g)}$	
Initial amount / mol	1.00	NA	0.00	0.00	Total amount = 1.00 mol
Amount at equilibrium / mol	0.70	NA	0.30	0.30	Total amount = 1.30 mol

$$P\ H_2O_{(g)} = ((0.70 \div 1.30) \times 100) = 53.85 \text{ kPa}$$

$$P\ H_{2(g)} = ((0.30 \div 1.30) \times 100) = 23.08 \text{ kPa}$$

$$P\ CO_{(g)} = ((0.30 \div 1.30) \times 100) = 23.08 \text{ kPa}$$

ii)

$$K_p = \frac{23.08 \text{ kPa} \times 23.08 \text{ kPa}}{53.85 \text{ kPa}}$$

$$K_p = \underline{9.92} \text{ kPa}$$

Question Five:

a) PV = nRT

∴ n = PV ÷ RT

Remember to convert all values into SI units:

P = 1590000 Pa   V = 0.00104 m^3 R = 8.314 $JK^{-1}mol^{-1}$ T = 380 K

n = (1590000 × 0.00104) ÷ (8.31 × 380)

n = 1653.6 ÷ 3159.32

n = <u>0.523</u> mol

0.523 – (0.122 + 0.298) = <u>0.103</u> mol of methanol

b)

$$K_c = \frac{[CH_3OH_{(g)}]}{[CO_{(g)}] \times [H_{2(g)}]^2}$$

$$K_c = \frac{(0.103 \div 1.04)}{(0.122 \div 1.04) \times (0.298 \div 1.04)^2}$$

$$K_c = \frac{0.099}{0.1173 \times 0.0821}$$

$$K_c = \underline{10.3}\ \text{mol}^2\text{dm}^{-6}$$

c)

i)

$$K_p = \frac{P\ CH_3OH_{(g)}}{P\ CO_{(g)} \times P\ H_{2(g)}{}^2}$$

ii)

mole fraction for $CO_{(g)}$ = 0.122 ÷ 0.523 = 0.233

mole fraction of $H_{2(g)}$ = 0.298 ÷ 0.523 = 0.570

mole fraction $CH_3OH_{(g)}$ = 0.103 ÷ 0.523 = 0.197

iii)

$P\ CO_{(g)}$ = 0.233 × 1.59 = 0.370 MPa

$P\ H_{2(g)}$ = 0.570 × 1.59 = 0.906 MPa

$P\ CH_3OH_{(g)}$ = 0.197 × 1.59 = 0.313 MPa

iv)

$$K_p = \frac{0.313}{0.370 \times 0.906^2}$$

$$K_p = \frac{0.313}{0.303}$$

$$K_p = \underline{1.03}\ \text{MPa}^{-2}$$