**Question 17** (Answer: **A**)

- The Contact process makes sulfur trioxide from sulfur dioxide and oxygen.
- All three species are gases in the converter, so all are labelled (g).
- $2SO_2(g) + O_2(g) \rightleftharpoons 2SO_3(g)$ – and $SO_4$ does not exist as a molecule.

**Question 19** (Answer: **C**)

- There are 4 moles of gas on the left and 2 on the right, so high pressure favours ammonia.
- The forward reaction is exothermic, so a *low* temperature favours ammonia.
- So increasing the pressure and decreasing the temperature both raise the yield.



**Question 18** (Answer: **C**)

- The forward reaction is endothermic, so *raising* the temperature shifts it to the right.
- More $NO_2$ means the mixture turns browner.
- Raising the pressure would shift it left, since there are fewer gas moles on that side, turning it paler.



**Question 19** (Answer: **A**)

- There are 2 moles of gas on the left and 1 on the right, so high pressure favours the ethanol.
- The forward reaction is exothermic, so a *low* temperature favours the ethanol.
- So raising the pressure and lowering the temperature both increase the equilibrium yield.

**Question 20** (Answer: **B**)

- The Contact process uses a vanadium(V) oxide catalyst – iron belongs to the Haber process.
- The pressure used is only slightly above atmospheric, about 200 kPa.
- A very high pressure is unnecessary here and would add cost for little gain.

| | |
|---|---|
| 4(a) | **M1** energy level of products below energy level of reactants<br><br>**M2** label of $SO_2(g) + 4HF(g)$ on product line<br><br>**M3** upward arrow labelled $E_a$ from energy level of reactants to the highest point of the curve<br><br>**M4** one downward arrow labelled $\Delta H$<br>AND<br>energy change starting from energy level of reactants and finishing at energy level of products |
| 4(b) | **M1** = (4 × S–F) + (4 × O–H) = (4 × 330) + (4 × 460) = 3160<br><br>**M2** bond energy of products – 3160 = –54<br>= 3160 – (–54) = 3214<br><br>**M3** (2 × S=O) + (4 × H–F) = 3214 therefore 2 × S=O = 3214 – (4 × 570) = 934<br><br>**M4** S=O = M3 ÷ 2 = 934 ÷ 2 = 467 |
| 4(c) | increased temperature:<br>**M1** (position of) equilibrium moves to left hand side<br><br>**M2** reaction is exothermic<br><br>increased pressure:<br>**M3** (position of) equilibrium moves to left hand side<br><br>**M4** less (gaseous) moles on left hand side<br><br>**M5** no change / catalyst does not affect position of equilibrium |
| 4(d) | **M1** kinetic energy of particles decreases<br><br>**M2** frequency of collisions between particles decreases<br><br>**M3** lower percentage/proportion/fraction of collisions / particles have energy greater than / equal to activation energy |

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**Question 16** (Answer: **B**)

- The forward reaction is exothermic, so a low temperature would give the best yield – but far too slowly.
- 450 °C is a compromise between yield and rate.
- High pressure genuinely favours the forward reaction, since there are fewer moles of gas on the right.

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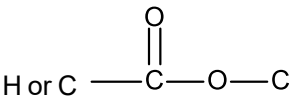
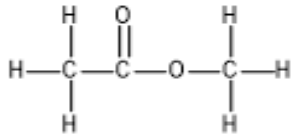
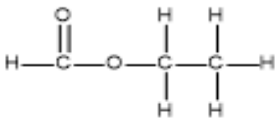
**Question 16** (Answer: **D**)

- The mixture's colour tells you which species dominates at equilibrium.
- Adding more of a reactant shifts the position to the right, deepening the red.
- Removing a reactant shifts it left, so the red fades towards yellow.

| | |
|---|---|
| 5(a) | **M1** concentration is no longer changing<br><br>**M2** rates of forward reaction and of the reverse reaction are equal |
| 5(b)(i) | **M1** rate decreases<br><br>**M2** yield of methanol decreases |
| 5(b)(ii) | no change(1) \| increases (1) |
| 5(b)(iii) | exothermic |
| 5(b)(iv) | **M1** copper<br><br>**M2** transition element |
| 5(c)(i) | **any 2 from**:<br>• same or **similar** chemical properties or reactions<br>• (same) general formula<br>• (consecutive members) differ by $CH_2$<br>• same functional group<br>• physical properties **OR**<br>example of a physical property<br>e.g. melting point /<br>boiling point /<br>volatility<br>vary in predictable manner **or** show trends **or** gradually change |
| 5(c)(ii) | $C_5H_{12}O$ |
| 5(d)(i) | **M1** displayed formula of ester linkage, i.e.<br>  <br><br>**M2** completely correct displayed formula of methyl ethanoate or ethyl methanoate<br>i.e.<br>  <br>OR<br>  |
| 5(d)(ii) | **M1** butan-1-ol<br><br>**M2** ethanoic acid |

| | |
|---|---|
| 5(e) | **M1** C 64.87 / 12<br>H 13.51 / 1<br>O 21.62 / 16<br><br>**OR**<br><br>5.41 13.51 1.35<br><br>**M2** $C_4H_{10}O$ |



**Question 20** (Answer: **D**)

- The forward reaction is exothermic, so *lowering* the temperature shifts it right.
- There are 9 moles of gas on the left and 10 on the right, so going forwards increases the volume.
- *Lowering* the pressure therefore also shifts it right.